Frontispiece.

Class K2 Passenger Locomotive.

Practical Instructor and Reference Book for Locomotive Firemen and Engineers

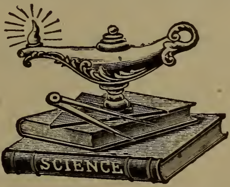
A PRACTICAL TREATISE

Covering in a thorough manner the railroad man's duties and how to properly perform them. It also contains up-to-date information on the Construction and Operation of Locomotives; Breakdowns, and Their Remedies; Air Brakes and Valve Gears, Rules and Signals. As a work of reference it cannot be excelled, as the information given cannot be found in any other similar treatise.

BY

CHARLES F. LOCKHART

Practical and Technical Locomotive Engineer



OVER EIGHT HUNDRED EXAMINATION QUESTIONS WITH THEIR ANSWERS ARE INCLUDED. THESE COVER THE EXAMINATIONS REQUIRED BY THE DIFFERENT RAILROADS AND THE INTERSTATE COMMERCE REQUIREMENTS

NEW YORK:

THE NORMAN W. HENLEY PUBLISHING CO.

132 NASSAU STREET

1916

COMPOSITION, ELECTROTYPING AND PRESSWORK
BY THE PUBLISHERS PRINTING CO., NEW YORK

INTRODUCTION

REALIZING that the Locomotive Engineer who is all practical without any technical knowledge of the construction and operation of the Locomotive is giving way to those who are more progressive, and who are ambitious enough to want to know the why and wherefore, the cause as well as the effect of the action of the different parts of the Locomotive;

Therefore in writing this Book the Author has endeavored to combine technical knowledge with practical experience in such a way that anyone may thoroughly understand the explanations given, describing the different parts in a manner which will be appreciated by the Fireman student or Engineer who desires a practical book of reference.

In writing this Book the Author has made use of the knowledge gained by practical experience as well as technical research, combining the practical knowledge gained by years of experience in the Locomotive Shops and on the Road as a Fireman and Engineer with the technical knowledge gained by a careful study of construction and operation.

Hoping that this book may prove to be the key which will unlock the door to a successful future for many an aspiring and ambitious Fireman and Engineer, I am yours in the interest of my fellow men and the elevation of the standard of our calling.

THE AUTHOR.

I take this opportunity of extending appreciation and thanks to my many friends who have helped to make my first book, INSTRUCTIONS FOR LOCOMOTIVE FIREMEN, a success.

Hoping that this Book (INSTRUCTIONS FOR LOCOMOTIVE FIREMEN AND ENGINEERS) will receive as kindly a reception as my first effort,

June, 1911 CHARLES F. LOCKHART.

PREFACE

INSTRUCTIONS FOR LOCOMOTIVE FIREMEN AND ENGINEERS is written for the purpose of giving the fireman that practical working information which is necessary to his success and to help him to advance himself to the highest point of efficiency as a fireman and then assist him to gain a practical working knowledge of the Locomotive that will enable him not only to pass a successful examination but to become a successful engineer as well.

For the convenience of the student in the study of this book, it has been divided into six parts, each part being complete in itself.

PART ONE

Part one treats of the fireman's duties and how to perform them, including a thorough and practical treatise on the subject of combustion.

PART TWO

Part two treats of the construction of the Boiler and the Engines. The different designs of Valve Gears, including the Walschaert, with a full description in detail of their action and operation.

PART THREE

Part three treats of Locomotive Break-downs and their remedies, including Injectors and Lubricators. A great deal of time has been spent on this part in order to make it thoroughly practical and up to date.

PART FOUR

Part four treats of the Westinghouse System of Air Brakes, giving a plain and thoroughly practical description of all its parts, including the E T Equipment, with the most frequent causes of failure and their remedies.

PART FIVE

Part Five treats of Locomotive running and economical operation, the Engineer and his duties, Personal Injuries and Deportment, with several other subjects pertaining to the Locomotive and of much interest to the Fireman and Engineer.

PART SIX

Part six consists of questions for examination, a complete review of each subject.

June, 1911. THE AUTHOR.

CONTENTS

PART ONE

PART TWO

PART THREE

PART FOUR

PART FIVE

PART SIX

ILLUSTRATIONS

PRACTICAL INSTRUCTOR AND REFERENCE BOOK FOR

LOCOMOTIVE FIREMEN AND ENGINEERS

Part One

THE FIREMAN'S DUTIES

1. To become a locomotive fireman the student will be required to make a sufficient number of trips under instruction of the engineer and fireman to learn his duties. When the engineer is satisfied that the student can do the work of a fireman alone, the engineer will sign him up as being capable of performing the duties of a locomotive fireman.

2. The fireman must report for duty at the required time.

3. He must examine the bulletin board before starting on each trip.

4. He must assist (when conditions require it) in placing the required supplies on the engine, such as oil-cans, lanterns, torches, shovel, etc.

5. He will then see that all the necessary equipment which is supposed to remain permanently on the engine are in their proper places, such as coal pick, fire-hook and scraper, grate shaker, tank bucket, etc.

6. He will see that the signal equipment is in good condition and ready for use.

7. The signal equipment consists of one red flag, two white flags, and four green flags; one red lantern, one white lantern, two classification lamps and two marker lamps. (Some roads require this equipment to include torpedoes and a fusee.)

8. The head-light, red and white lanterns and markers must be lighted at sundown and put out at sunrise, except when the view is obscured by fog or other causes, when lights may be used.

9. The classification lamps will be lighted and set to show green or white only by instruction of the engineer.

HOW TO FILL THE LUBRICATOR AND OTHER DUTIES

10. The first move to be made in filling the lubricator is to see that all steam valves in connection with it are closed, by turning them to the right.

11. Now open the drain cock at the bottom of the lubricator and drain all of the water out of the bowl. It may be necessary to loose the filling plug at the top of bowl before all of the water will run out; then remove the filling plug and close the drain cock.

The lubricator is now ready for filling; fill the bowl with valve oil and replace the filling plug; now open the steam valve and the condensing valve wide open.

After the oil has become thoroughly heated in the lubricator the feed valves may be opened and adjusted to feed at the required rate.

12. After filling the lubricator the fireman will see that the cab is swept out, the boiler head wiped off, and the windows cleaned.

13. The fireman will now see that the fire is in proper condition for beginning the trip.

14. While on the road the fireman will endeavor to fire in such a manner as to maintain an average pressure of steam on the boiler.

The average pressure should be just a little less than the pressure at which the safety valves are set to open.

15. The fireman will take water and coal, and assist the engineer in making repairs when necessary. He will assist the engineer in keeping a look-out on the track for signals or obstructions, and call the indication of signals to the engineer. The fireman will take charge of the engine in the absence of the engineer.

16. He must not run the engine in the absence of the engineer, unless in some emergency he is directed to do so by the conductor or some one in authority.

17. The fireman must protect the front end of the train when necessary.

18. At the end of the trip he will assist in removing the supplies which are assigned to the engineer from the engine, when required.

19. The engineer turns in a time slip for the trip. The fireman's time is taken from this slip.

20. After the time slip has been turned in at the end of the trip the fireman is then relieved until called to go on another trip.

21. The fireman must be familiar with the rules that

apply to the protection of trains, and the use of signals which he must be prepared to use promptly.

22. The fireman reports to and receives his instructions from the Road Foreman of Engines or Master Mechanic.

23. He must obey the orders of the Superintendent and Train Master.

24. When at the engine-house he is under the directions of the Engine-house Foreman.

25. When with the engine, the fireman must obey the orders of the Engineer respecting the proper use of fuel and performance of his duties.

The fireman must be familiar with the following signals:

COLOR SIGNALS

26. Red—Means stop.

White—Proceed.

Green—Proceed with Caution (and for other uses prescribed by the rules).

Green and White—The Combined green and white is to be used to stop a train only at the flag station indicated on the schedule for that train.

Blue—Is a signal used by car repairers and air-brake inspectors to protect themselves while working about cars or engine.

While thus protected the cars or engine must not be moved until the signal has been removed by the same workmen who placed it there, and any obstruction must not be placed so as to obscure the view of such a signal.

27. A Fusee on or near the track, burning red, must

not be passed until burned out. When burning GREEN it is a caution signal.

HAND, FLAG AND LAMP SIGNALS

28. Swung across the track, STOP.

Raised and lowered vertically, PROCEED.

Swung vertically in a circle at half arm's length across the track, when the train is standing, BACK.

Swung vertically in a circle at arm's length across the track, when the train is running, TRAIN HAS PARTED.

Swung horizontally above the head when train is standing, APPLY AIR BRAKES. Held at arm's length above the head when train is standing, RELEASE AIR BRAKES.

Held horizontally at arm's length when train is moving, reduce speed.

ANY OBJECT WAVED VIOLENTLY on or near the track is a signal to stop.

ENGINE STEAM WHISTLE SIGNALS

29. One short blast of the whistle means STOP. Apply brakes.

Two long blasts—Release Brakes.

One long, three short—Flagman go back to protect the rear end of train.

Four long—Flagman return from the west or south on passenger track.*

Four long, one short—Flagman return from west or south on freight track.*

* Where three or more tracks are used as running tracks.

Five long—Flagman return from east or north on passenger track.*

Five long, one short—Flagman return from east or north on freight track.*

Three long when train is running—Train parted.

Three short when train is standing—Back the train.

Three short when train is running—Answer to conductor's signal to stop at next station.

Four short—Is a call for a signal.

Two short—Is an answer to any signal not otherwise provided for.

One long, two short—Used to call attention of other trains of the same or inferior class, that signals are being displayed for a following section.

Two long, two short—Used when approaching public road crossings at grade.

One long—Approaching stations, junctions, railroad crossings, etc.

A succession of short blasts of the whistle is a danger signal.

The explosion of two torpedoes, not more than two hundred feet apart, is a signal to reduce speed, and look out for a stop signal. One torpedo means the same as two, but the use of two is required.

AIR WHISTLE SIGNALS USED IN PASSENGER SERVICE

30. Two blasts when train is standing—START.

Two when train is running—STOP AT ONCE.

* Where three or more tracks are used as running tracks,

THREE when train is standing—BACK.

THREE when train is running—STOP AT NEXT STATION.

FOUR when train is standing—APPLY OR RELEASE AIR BRAKES.

FOUR when train is running—REDUCE SPEED.

FIVE when train is standing—CALL FLAG.

FIVE when train is running—INCREASE SPEED.

COMBUSTION

31. A chemical analysis of the elements entering into combustion together with their change in form and effect during the process of combustion proves that a careful study of the subject will be of great value to the locomotive fireman or engineer, not only in the economical use of fuel and abatement of smoke, but in general efficiency and the saving of labor as well.

32. The process or action of fire in consuming a body, as the burning of wood or coal, is generally known as combustion.

33. Combustion is accomplished by the union of an inflammable substance with oxygen.

In the burning of a substance heat is disengaged or thrown off and oxygen is absorbed.

Combustion therefore is the disengagement of heat, or heat and light, which accompanies certain forms of chemical combination.

34. Bituminous coal being the fuel most generally used by the different railroads, we will first consider its composition, and then the relation of other elements to its

composition, and the effect they have in obtaining the most effective combustion.

Bituminous coal is composed of from 50 to 80 parts fixed carbon.

Table showing the average analysis of Ohio coal.

Fixed carbon	61 per cent.
Volatile matter	33 " "
Ash	$3\frac{3}{4}$ " "
Sulphur	1 " "
Moisture	$1\frac{1}{4}$ " "
Total	100 per cent.

THE ATMOSPHERE

35. The atmosphere is a mechanical mixture and its two main constituents exist very nearly as follows in volume: Oxygen, 20.61 per cent; nitrogen, 77.95 per cent.

Table giving the average composition of air in detail.

Oxygen	20.61 per cent.
Nitrogen	77.95 " "
Carbon dioxide	0.04 " "
Water vapor	1.40 " "
Nitric acid	Trace.
Ammonia	"
Total	100 per cent.

36. Table showing the composition of water.

Oxygen	88.8 parts by weight.
Hydrogen	11.1 " " "
Carbon	.1 " " "
Total	100 parts by weight.

In order that the meaning of all the terms used in explaining the composition of the different elements necessary to combustion may be thoroughly understood, a list of definitions is given.

DEFINITIONS

37. CARBON—An elementary combustible substance, existing pure and crystallized in the diamond, and sometimes in graphite, and forming the basis of animal and vegetable charcoal and coke. It is the chief constituent in coal.

38. CARBON DIOXIDE—With water gas, is the product of complete combustion.

39. CARBON MONOXIDE—With water, vapor is the product of incomplete combustion.

40. HYDROGEN—One of the elements of water, of which it contains one-ninth part. Hydrogen gas is the lightest body known; it is extremely inflammable.

41. OXYGEN—Is the vital part of the atmosphere, and is the supporter of combustion.

42. NITROGEN is the principal ingredient of atmospheric air, and under ordinary conditions is non-combustible; its chief function is to dilute the oxygen.

THE PROCESS OF COMBUSTION IN DETAIL

43. The minimum quantity of air required for the combustion of one pound of bituminous coal is 143 cubic feet, but under ordinary working conditions from 225 to 250 cubic feet is required.

44. When carbon burns in a free current of air with ample oxygen present to complete the combustion, 12 parts by weight of carbon unite with 32 parts of oxygen to yield carbon dioxide.

45. Hydrogen is expelled from the coal at a fairly low temperature in combination with some of the carbon. This combination of gas is inflammable at a fairly low temperature, producing a flame which surrounds the fuel heating it and producing more gas. This leaves the remainder of the fuel in a porous condition and helps to make the combustion more complete.

46. The more pure carbon the coal contains the less flame will be produced by its combustion.

47. Soft coal consists to a large extent of volatile matter. All of the hydrogen or hydro-carbons of the volatile portions burn first; then if there is a sufficient amount of oxygen, the carbon combined with the hydro-carbons burns and finally the fixed carbon. This action does not take place separately but forms a combination.

48. The elements entering into combustion with oxygen are hydrogen and carbon, the hydrogen burning to water vapor, and the carbon producing either carbon monoxide or carbon dioxide, according to the volume of oxygen present.

49. Water vapor and carbon dioxide are the results of complete combustion.

50. Water vapor and carbon monoxide are the results of incomplete combustion, the carbon monoxide being capable of further combustion with a fresh supply of air.

51. Under ordinary conditions when building a fire in

a furnace about one and one-half to two per cent of the carbons and hydro-carbons liberated escape from the stack unconsumed, but as the mass of fuel becomes thoroughly ignited and the furnace heated, the volume of smoke becomes much less. As the temperature of the furnace is now increased to a point where nearly all of the combustible gases are being consumed, the fire will burn clear and bright.

52. When a fresh supply of coal is fired, the temperature of the fuel and the quantity supplied will exert some influence on the temperature of the furnace.

53. In order to ignite the new fuel it must be heated to a temperature of a little over 1,800° Fahrenheit.

54. If a large quantity of coal is fired at each firing, the temperature of the furnace will be reduced to such a degree that all of the combustible gases will not be consumed. The result will be a large volume of smoke, and a corresponding loss in the amount of effective heat generated per pound of coal consumed.

55. In order to secure the greatest per cent of efficiency per pound of coal, it should be fired often in a quantity that will just supply the rate of consumption.

56. The smoke which is expelled from the stack of a locomotive is composed of a very complex mixture and consists of unburnt carbon, tar vapor, and carbon monoxide gas, with small particles of ash and coked coal, which are drawn from the furnace by the force of the draft.

57. The density of the smoke depends particularly on the volume of unconsumed carbon which it contains.

The gas arising from this volume of cooling carbon is monoxide gas and is very poisonous, and if breathed in large volumes, amounting to five per cent of the atmosphere, will cause death.

58. A British thermal unit is the amount of heat required to raise one pound of water 1° Fahrenheit.

59. One pound of coal will produce from 11,500 to 14,000 British thermal units.

60. And evaporate from five to eight pounds of water.

61. The latter per cent of efficiency is seldom obtained because of the loss from several sources, such as improper firing, defective draft, faulty construction, and carelessness in the care of the boiler.

62. The rate of combustion varies according to the nature of the service, and will fluctuate between 20 and 140 pounds per square foot of grate surface per hour.

63. The average evaporation is about seven pounds of water per pound of coal.

64. A gallon of water weighs eight and one-third pounds, and if one gallon of water is evaporated per pound of coal, it is considered exceptionally good.

65. It has been shown that air is just as necessary as coal to produce combustion.

66. When no heat is lost and perfect combustion is obtained as in a testing plant, only 143 cubic feet of air is necessary to burn one pound of coal, but in actual practice with the locomotive about 19 pounds or 250 cubic feet of air per pound of coal is necessary to insure complete combustion.

67. The supply of air to the furnace should be regulated in proportion to the amount of fuel to be consumed.

68. By admitting too much air to the furnace the excess draft will cool the gases below the igniting-point; the excess air, becoming heated, passes out through the stack at a high degree of temperature, carrying a large quantity of unconsumed gases with it.

69. Air must be admitted to the furnace in such a way and in such volume that the temperature necessary to burn the coal and gases can be maintained.

70. Most of the air necessary to complete combustion can be admitted through the grates, passing up through the fire, burning the coked coal first, and forming carbon dioxide. As the air comes in contact with the fresh coal on the surface of the fire and joins with fresh carbon, carbon monoxide is produced.

71. If sufficient oxygen is not present at this time, a part of the gases will pass out through the stack unconsumed, but if a fresh supply of air is admitted to the surface of the fire, the carbon monoxide will combine with the oxygen in the air thus supplied and form carbon dioxide, completing combustion.

72. A small amount of air admitted to the fire-box above the surface of the fire, especially when the fire has become dirty, is very beneficial, and for that reason the dampers in the fire door should be regulated accordingly.

73. The front dampers of the ash-pan should be kept closed as long as sufficient air can be supplied through the back ones.

74. The highest temperature that can be maintained in

the fire-box under ordinary conditions by the combustion of bituminous coal is a little over 2,000° Fahrenheit, 2,200° Fahrenheit being the maximum heat obtainable under working conditions.

75. The greater part of the heat produced by the combustion of coal in the fire-box is absorbed by the water in the boiler and it is due to this fact that the furnace is kept from attaining a higher temperature.

METHODS OF FIRING

76. In firing locomotive boilers there are three different systems, each one of them having its successful advocates.

They are known as the coking or bank fire, the graduated or wedge-shaped fire, and the level fire.

THE BANK FIRE

77. The coking or bank fire is fired very heavy around the fire door, the fire being kept comparatively light toward the flues.

As the coal becomes coked around the door it is shoved forward and a fresh supply of coal is fired around the door.

This method is economical, but does not make steam as fast as the other methods; it also tends to cause leakage around the fire door and flues.

THE GRADUATED FIRE

78. The graduated or wedge-shaped fire is built up with a gradual slope from the fire door forward, being kept bright all over and fired at frequent intervals.

This fire has some advantage over the level fire because it forces a good draft through the fire near the flues, keeping it clear and bright and preventing sparks from gathering in the forward end of the fire-box as is often the case with a level fire.

THE LEVEL FIRE

79. A level fire is one which is kept level all over the grate surface. This method is the one technically considered the best on account of the even draft which it allows to pass through every part of the fire with a corresponding efficiency in combustion; but this fire is not a general favorite among firemen, because with the wide fire-box and strong draft it is almost impossible to keep the fire level as it has a tendency to burn out in spots rather than to burn even all over the grate surfaces.

It also has a tendency to accumulate sparks in the front end of the fire-box.

80. With small fire-boxes the level fire is the only practical one, but with the larger class of engines with large wide fire-boxes the graduated or wedge-shaped fire seems to give the best results and is the one most generally used.

81. While working in city limits the fireman is required to make just as little smoke as possible.

82. This may be accomplished by firing light and as often as the service demands, opening the fire door a few inches just after each new supply of coal has been fired and opening the blower valve a few turns—this will clear up the smoke. The fire door may then be closed until it is necessary to put in another fire.

83. The fire should never be hooked except when banked or when a crust has formed over it; the hook may then be used to break the crust so that a draft may pass through it. Care should be exercised in hooking a fire as excess or careless hooking will cause the fire to clinker.

84. The grates should be shaken very sparingly at the start or beginning of a trip, as there is only green coal and fire on the grates; there is liability of breakage by shaking the grates while they are hot.

It also causes live coals to fall through into the ash-pan, which is very undesirable.

85. After the ashes have begun to gather on the grate surface, the grates may then be shaken at frequent intervals or as often as necessary to remove the dead ashes and allow the proper draft to pass through the fire.

86. The dampers should be kept closed or nearly so at the beginning of the trip to prevent tearing the fire; after the fire has been built up, the dampers may then be adjusted to allow the proper draft.

87. The fire door should be closed between each shovelful of coal to keep the cold air from cooling the upper surface of the fire and chilling the flues, as this frequently causes flues to leak.

88. The blower is used to cause a draft through the furnace to clear up the smoke and to brighten the fire, in order to raise the steam pressure on the boiler when the engine is not working.

89. If the water in the boiler should get dangerously low, none showing at the lower gauge cock, protect the crown sheet at once by opening the fire door and turning

on the blower, then cover or kill the fire. The fire may be covered with fine damp coal, sand, slag, gravel, sod, or any other non-combustible which can be secured.

ADDENDA TO PART ONE

With the foregoing information any one can prepare himself not only to pass a successful examination, but to become a successful fireman as well.

The different railroad companies are very careful in the selection of their firemen, because they expect them to become engineers, in whom they must place a great confidence and upon whom must rest a great responsibility, as not only thousands of dollars of the company's property is placed daily in the hands of their firemen and engineers, but hundreds of lives depend upon each one doing his duty.

The fireman's success or failure will depend almost wholly upon his own individual effort.

The young man who thinks that all a fireman has to do is ring the bell and draw his salary had better disabuse his mind of that idea.

The nature of the work requires a great deal of physical strength and endurance, as well as ability to act quickly and with good judgment in case of emergency.

His duty to his employer demands that he give him the best that is in him and any shirking of his duty is robbing his employer of what is justly due him, and not only that, but he is robbing himself of the satisfaction of work well done.

There is plenty of room and opportunity for the young man who is willing to put forth the effort necessary to advance himself.

It is a rule of all the railroad companies that a person to be advanced must show capacity for increased responsibility.

The fellow who shirks his duty, finds fault with his employers and his work, and is not willing to give good service for a reasonable compensation, will soon find himself crowded out to make room for those who are more willing and ambitious.

Different railroad companies maintain discipline among their men in different ways, but the system in general use is as follows:

This system of discipline first finds expression in the Standard Book of Rules, then in the Orders and Instructions of the different officials.

Failure to comply with these rules, orders, or instructions will subject him to discipline which will be administered by reprimand, suspension, or discharge, according to the seriousness of the offense.

There are two things which are demanded of every employee—truthfulness and sobriety.

Truthfulness to insure fair dealing and sobriety to insure the company that he is going to use all the good sense and judgment with which he has been endowed in the performance of his duties and not endanger the lives of his fellow men and the company's property by becoming intoxicated.

Part Two

GENERAL DESCRIPTION OF THE LOCOMOTIVE, ITS CONSTRUCTION AND OPERATION

THE BOILER

90. A locomotive boiler is a vessel formed of steel plates or sheets to contain the water and steam after it is generated, and is so constructed that it contains an internal fire-box. A barrel extends from the fire-box section forward to a smoke-box on the front end, on which is placed the smoke-stack. The fire-box and the smoke-box are connected by a number of flues which conduct the smoke, sparks, etc., from the fire-box to the smoke-box, from which the smoke is expelled by the draft through the stack.

91. This style of boiler, having an internal fire-box and a barrel with flues extending through it to a smoke-box, is known as a tubular boiler.

92. Locomotive boilers are made of steel plates, they are carefully tested for defects before being used, and are subjected to a test for tensile strength of from 55,000 to 65,000 pounds per square inch with an elongation of 25 per cent.

A piece cut from a sheet for test purposes should stand bending double either hot or cold and not show any fracture.

93. Boiler plates are carefully tested for the following qualities:

94. Tensile strength, to insure a strength which will overcome all ordinary strains to which it may be subject and also that the plates may be no thicker than the pressure to which it is subject requires.

95. Toughness and elasticity to resist corrosion and the strain to which it is subject in manufacture.

96. Ductility, so that the boiler may withstand twisting and bending strains to which locomotive boilers are always subject.

97. Boiler plates are bent and forged into the proper shape and then securely riveted together.

98. Circumferential seams are usually riveted with two rows of rivets while longitudinal seams are riveted with three and sometimes four rows; the reason for this difference is that the strain on the longitudinal seams is almost twice as great as that on the circumferential seams.

99. Single riveted lap joints have about 56 per cent of the strength of the plate, while double riveted lap joints have about 75 per cent of the strength of the plate.

100. Butt joints are used for longitudinal seams, while lap joints are used for circumferential seams.

101. A butt joint is one in which the edges of the plates have been butted together on the same plane and the seam overlaid with a strip of plate and securely riveted by one or two rows of rivets on each side of the center seam. This kind of a joint, if two rows of rivets are used on each side of the center seam, is considered to be equal to the strength of the plate.

102. The fire-box is constructed of five sheets:—the crown sheet, the flue sheet to which the flues are attached, two side sheets, and a door sheet in which the furnace door is placed.

103. The fire-box is placed inside of the outer shell of the boiler, the two being joined at the bottom by means of a large ring called a mud ring to which they are riveted. This mud ring, being from four to five inches thick, it separates the fire-box sheets from the shell by that distance.

104. The side sheets, door sheet, and part of the flue sheet are secured to the outer shell of the fire-box by means of stay bolts screwed through both sheets and riveted on both ends.

105. The crown sheet is supported by means of crown bolts. The crown bolts are much longer and larger than the stay bolts. As the crown sheet is placed from 18 to 24 inches from the top shell of the boiler, stay rods are attached to the boiler head and top shell of the boiler and to the front flue sheet and the shell, for the purpose of taking up some of the lateral strain on these parts.

106. The barrel of a boiler needs no staying, as cylindrical surfaces are self-supporting, the internal pressure tending to maintain the cylindrical form.

107. Flat surfaces are not self-supporting and therefore must be stayed.

108. The water leg of a boiler is the space between the inside and outside sheets of the fire-box.

109. The dome is placed on the top of the boiler for the purpose of allowing the steam to rise to some distance above the water level, thereby losing some of its moisture

before entering the dry pipe through the throttle valve which is placed in the dome.

110. The flue sheet is held in place by means of the flues which are attached to it.

111. That part of the boiler extending from the barrel

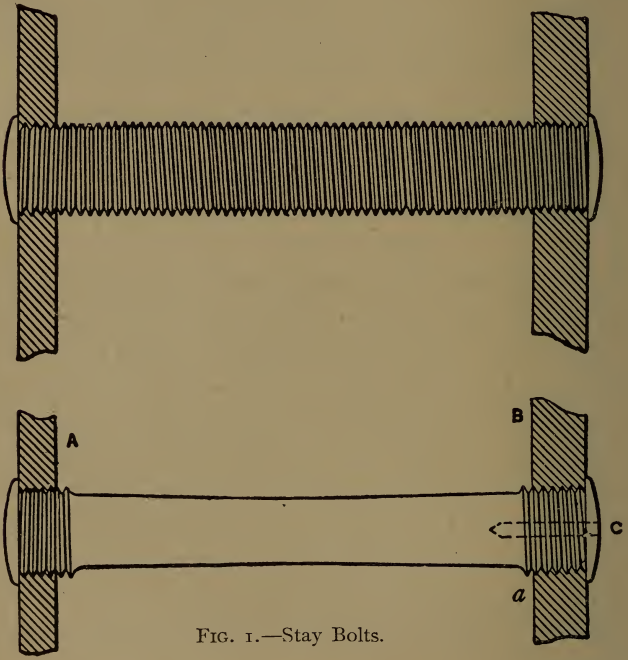


Fig. 1.—Stay Bolts.

to the lower edge of the fire-box is called the throat sheet.

112. The round part extending from the fire-box section to the smoke-box is called the barrel. To the lower side of the smoke-box is attached a spark hopper for cleaning out the sparks that are accumulated by reason of the

netting which is placed in the smoke-box. This netting prevents the hot sparks from being thrown out along the right-of-way, causing damage by fire, etc.

113. A draft apron, which is used to regulate the draft through the fire, so that it may burn even all over the grate surface, together with the steam pipes which carry the steam from the dry pipe to the steam ports in the cylinder saddle, are located in the front end or smoke-box.

NAMES OF THE DIFFERENT PARTS OF THE BOILER

114. The Shell, Fire-box, Barrel, Smoke-box, Stack, Dome, Mud-ring, Flues, Throttle Valve, Dry Pipe, Steam Pipes, Netting, Draft Apron, Racks to hold grates in the bottom of the fire-box, Steam Bracket or Spider, which is attached to the dome and extending into the cab to which the injector, steam pipes, the blower pipe, steam pipes to which the air pumps and lubricator are attached.

115. There are hand holes provided in the sides of the smoke-box for convenience in cleaning the sparks out of the same.

116. A blow-off cock is placed in the lower edge of the throat sheet for the purpose of draining the steam and water out of the boiler.

117. There are washout plugs and plates placed at different places in the shell of the boiler for convenience in washing out the mud and scale which gathers in the boiler from the feed water.

118. A safety valve is attached to the top of the dome

and is set to open and relieve the pressure in the boiler when the pressure exceeds the maximum pressure desired.

119. The broad grate surface or Atlantic type fire-box is generally used.

120. The boiler is placed horizontally on steel frames to which the engine's running gears, etc., are attached.

THE ENGINES

121. While there are many different classes and designs of Locomotives, there are only two kinds of engines used in their construction. They are known as the Simple Engine and the Compound Engine.

122. A Simple Engine is one which admits steam to the cylinder during a part of the stroke and expands it during the remainder and then exhausts to the atmosphere.

123. A Simple Locomotive Engine is double-acting, single expansion, non-condensing, and non-compounding.

124. A Compound Engine admits steam first to a high-pressure cylinder where it partly expands in doing its work. It is then exhausted into the steam chest of another larger cylinder, called a low-pressure cylinder; when the steam is admitted to this cylinder it completes its expansion and then is exhausted to the atmosphere.

125. The Compound Engine is double-acting, double-expansion, compounding, non-condensing.

126. The Compound Engine is economical from the standpoint of consumption of fuel, but the cost of maintenance and the frequency of road failures has caused most

of the railroads to discard them in favor of the Simple Engine.

127. The Locomotive has two engines which are attached in a horizontal position to each side of the heavy frames which support the boiler.

128. The Engines are connected by being attached to crank-pins in the drive-wheels which are attached solid to the main shaft or axle.

They are so connected that they work in perfect harmony with each other.

129. When one engine is passing the center or at the end of the stroke, the other engine will be exerting full power or at its strongest point, so that it is impossible for both engines to get on the center at the same time.

130. The Locomotive is designed for the purpose of furnishing its own tractive power, as well as power to draw a heavy load.

131. All of the driving wheels of an engine on each side are connected to the main crank or driving wheel by side rods so that all wheels move at the same time, thereby dividing the strain on the frame of the locomotive.

132. The Engine cylinder casting is connected to the barrel of the boiler, smoke-box, and frame in such a way that the steam pipes in the smoke-box may be connected to the part of the cylinder casting known as the cylinder saddle, which has ports cast in it to conduct the steam from the steam pipes to the steam chest, also a port to conduct the steam, after it is used in the cylinder and returns to the steam chest, to the monument, stack, and open air.

133. There are two other ports in the cylinder casting, one at each end of the steam chest or valve seat, which also connects with each end of the cylinder.

Through these ports the steam is admitted (by the valve in the steam chest) into the cylinder and after doing its work in the cylinder, is again exhausted through the same port by the movement of the valve.

134. A piston-head and rod are placed in the cylinder; the piston-rod, on one end of which is placed the piston-head, passes through a hole in the rear cylinder-head and is attached to a cross-head which works in guides attached to the cylinder casting and a guide yoke. One end of the main rod is also connected to the cross-head and the other end to the pin in the main driving wheel.

135. The reciprocating or to-and-fro motion of the piston is changed to circular motion by connecting the main rod to the pin in the drive wheel. As has been explained, the front end of the main rod is attached to the cross-head, which is keyed to the piston.

136. When steam is admitted to the cylinder it presses against the walls of the cylinder, the cylinder head, and the piston. As the piston is the point of least resistance, it will be forced to move; this movement is transmitted through the main rod to the crank-pin and wheel to which it is attached.

137. If the crank-pin is at any point of its circle which forms an angle to the center line of motion of the main rod, the force which the steam exerts against the piston will be exerted against the pin, forcing it to move in a circle around the axle.

138. Should the pin be in line with the center of the axle and the front end of the main rod, it will not move because the force is exerted directly against the center line of motion.

139. Each engine has two centers—the forward center and the back center.

140. The engine is on its forward center when the piston has completed its forward stroke.

141. The engine is on its back center when it has completed its backward stroke.

142. The forward and back centers of an engine are sometimes called the dead points of circular motion. In starting the locomotive the crank-pin of one engine is forced over or carried past the dead points by the engine attached to the wheel on the opposite end of the main axle.

143. With stationary engines large fly-wheels are used to carry the engine over its dead points, but the wheels of a locomotive which are used to carry the weight as well as to impart locomotion cannot be used for the purpose of carrying the engine over its centers because the speed of the engine would oftentimes (as in starting a heavy train) be too slow to impart momentum enough to enable the engine to pass its center line or dead points.

RECIPROCATING AND CIRCULAR MOTION

144. In changing the to-and-fro or reciprocating motion of the piston to the circular motion of the main pin, a condition is created which is known among technical engineers as angularity. This angularity exists in every

case when a connecting part moves out of a direct line to its axis or center line of motion.

145. When the main pin is on the forward center in the forward movement of the engine, and moves to the bottom quarter, the pin will have completed just one-fourth of its complete circle, but the piston and cross-head will have completed slightly more than one-half of their stroke. The pin now moves to the back center at which point the piston and cross-head will have just completed their stroke, so that the piston and cross-head must have traveled faster and farther while the pin was moving from the forward center to the bottom quarter than it did in moving from the bottom quarter to the back center.

146. The reason for this seemingly erratic movement is the increase in the angularity of the main rod, as the pin moves from the center line of motion to the bottom quarter which with the top quarter is the farthest point from the center line and the point at which the greatest amount of angularity exists in the position of the main rod.

147. The real difference between the length of straight and angular lines is shown in Fig. 2. This illustration shows the cross-head at exactly the center of the stroke and the center of the pin bearing in the butt end of the main rod directly over the center of the axle; the butt end of the main rod is now lowered, but it does not reach to the bottom quarter. This shows how much farther it will be necessary for the piston and cross-head to travel before the difference in the distance occasioned by the angular position of the rod can be overcome.

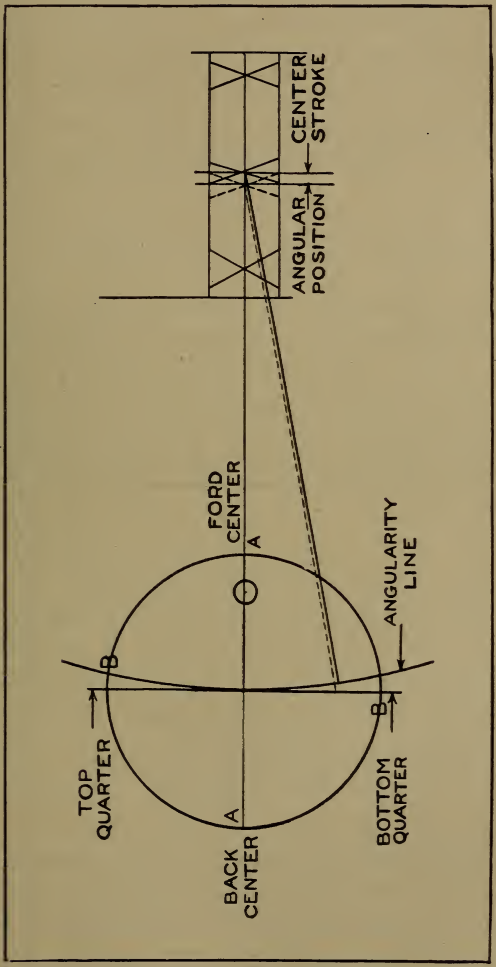


Fig. 2.—Angularity of Main Rod

148. The angularity of the rod increases during the first part of the stroke because it is traveling away from the center line and decreases during the latter part of the stroke because it is traveling back toward the center line.

149. The point at which the greatest pressure is exerted on the pin is while it is moving from a point as shown in Fig. 2 from *a* to *b*. The point shown at *b*, being subject to change, is the point of cut-off, which is the point at which the ports for the admission of live steam to the cylinder are closed. This is further explained under the head of Valves and Valve Gears. From *b* the pressure decreases until the steam is exhausted from the cylinder.

150. This change in the pressure on the pin during the different parts of its stroke causes the pin to wear the most on the parts where the greatest friction occurs.

THE PISTONS

151. The piston-rod is made with a taper-fit on each end. The piston head, which is made of cast steel and is dish-shaped, is forced on to the taper-fit on the front end of the rod by hydraulic pressure and is made more secure by a nut which is screwed on to the end of the piston, helping to force the head more tightly on the taper-fit on the rod.

152. Steam is prevented from leaking around the flange of the piston head by means of cylinder packing rings which are sprung into grooves in the piston head; these rings expand against the walls of the cylinder and prevent leakage.

153. A key-way is cut through the end of the piston-rod which is drawn in to a taper-fit in the cross-head. The cross-head is also provided with a key-way through its piston connection.

A key is driven through the cross-head and piston-rod, attaching the rod solid to the cross-head.

CROSS-HEADS AND GUIDES

154. In order to carry the piston-rod through the cylinder head in a straight line, it is necessary to provide some form of guides and a cross-head.

155. If a cross-head and guide were not used, the piston-rod would become bent, and the piston cocked in the cylinder. It would be impossible to keep the packing from blowing and would probably result in broken parts and serious damage.

156. The guides are attached to the rear cylinder head and a guide yoke which is bolted to the frame of the locomotive.

157. The two bar guides are most generally used. They are made of heavy flat steel bars. They are placed one above the other and far enough apart to allow the cross-head to slide between them.

158. The cross-head used with the two-bar style of guides is made of one piece; a large hole is drilled through it in which is placed a steel wrist-pin.

Some cross-heads have removable plates or shoes which can be relined and the lost motion taken up by running babbitt metal into them and then planing it off to the required thickness. Other styles of cross-heads have brass gibbs or plates attached to the shoes; these plates may be raised to take up the lost motion by placing strips of tin or metal between the shoe and the gibb.

159. The pressure or friction on the top and bottom guides is not the same when the engine is running forward and backward.

160. When the engine is running forward and the piston is traveling backward the cross-head will be forced against the top guide; as the piston starts forward in the cylinder and the main rod begins to pull instead of shove the pin, the cross-head is again forced against the top guide, but if the engine be reversed and run backward, the bottom guide will receive nearly all the strain. This is caused by the difference in the position or angle of the main rod in the forward and backward motions.

MAIN RODS

161. The main rods of the late designs of locomotives are made of steel and are I-shaped; they are made in this form because it is much stronger in proportion to its weight than a square bar.

162. The crank or butt end of the main rod is made with an open jaw. Brasses are placed in these jaws which are fitted to the main pin; a filler block is placed between the ends of the two jaws and a large bolt placed through both jaws and the filler block. Keys are placed in front and sometimes back of the brasses for the purpose of

taking up the lost motion in the bearings. These keys are held in place by set screws.

163. The manner of keying up the front end of the main rod is as follows: The key passes through a slot across the rod, the key has a bearing against a wedge block which, in turn, has a bearing against the brass; a nut is screwed on to the bolt end of this key. A jamb nut is also used to prevent the key from working loose, a hole is drilled through the bolt end of this key, and a cotter key placed in it as an extra precaution against the nuts working off and the key losing out.

PARALLEL RODS

164. The parallel or side rods are made of the same kind of material as the main rods, but the manner of putting the bearings in the rods is different. The side rods have brass bushings pressed into them; these bushings cannot be adjusted when worn and the only way to overcome the lost motion occasioned by the wear of the parts is to replace them with new ones.

The style of side rods used on nearly all of the old-style engines have keys through the rods on each side of the brasses which, in this case, are made in two parts. By driving these keys down, the brasses were forced together, taking up the lost motion caused by the wear of the parts; these keys are held in place by jamb nuts and set screws. Great care must be used in the adjustment of these keys as improper adjustment would cause friction and possible breakage of the rods.

THE DRIVING WHEELS

165. Driving wheel centers are made of cast steel. A steel tire is turned out slightly smaller than the circumference of the wheel center; the tire is then heated and expanded until it is large enough to slip over the wheel center; it is then cooled off, shrinking on the center with enormous pressure.

166. Locomotive driving wheels are provided with counterbalances; these counterbalances are used for the purpose of balancing the weight of the rods and their connections.

167. The counterbalance is placed opposite to the pin and as near the rim of the wheel as possible, so that when the wheel is revolving it will turn with a steady motion. In this way the throw or unequal energy exerted by the centrifugal force of the parts in motion is overcome, but the reciprocating parts and their weight or the inertia caused by the dragging or friction of the parts cannot be equalized by adding counterbalance, except in one way, as it would have the same tendency to overbalance the wheel vertically to the same extent that they balance the reciprocating parts horizontally.

168. Any additional overweight in the counterbalance which is not necessary to balance the parts and produce a good riding engine is a detriment not only to the engine itself but to the track and bridges over which it runs.

THE CRANK-PINS

169. The crank-pins are made of wrought iron or steel. When made of wrought iron they are case-hardened, so as to withstand the greatest amount of wear possible; but steel is now generally used for making crank-pins.

The main pin has two journals, the inside journal being the side rod connection and the outside journal the main rod connection; the other pins have single journals to which the side rods are connected.

170. Holes are bored through the wheels and the pins are turned to fit the hole very tightly; the pin is then forced into the wheel by hydraulic pressure of several tons; the pin is then riveted on the inside of the wheel.

171. Some engines have the collars on all the pins except the main, made in the form of a bolt with a very large flat head. The head, being the collar of the pin and the bolt passing through a hole drilled lengthwise through the center of the pin, is fastened by a nut. On the inside of the wheel a hole is drilled in cross-section through the end of the bolt in which is placed a cotter key to prevent the nut from working off; a short stud is placed in the outer end of the pin which fits a small hole in the collar. This pin prevents the collar from turning and working loose.

THE DRIVING AXLES

172. Locomotive driving axles are made of steel and are tested very carefully for defects and tensile strength.

173. Driving axles are now made without any shoulder

inside of the journal and the center of the axle is usually a little smaller than the journals.

174. The wheels are pressed on the axles at a pressure of about 65 tons; they are then keyed on the axles.

LOCOMOTIVE FRAMES

Because there are so many different types of locomotives it will be impossible and really unnecessary to try to explain them all.

175. Locomotive frames are made of hammered iron or open-hearth steel and are subject to a very high test for tensile strength.

DRIVING BOXES

176. Driving boxes are made of cast iron in the form of the letter U, inverted; they are provided with bronze crowns. The boxes are placed on the axle just inside of the wheels. The boxes have bearings on the axles to carry the weight of the locomotive and bearings on the side against the hub of the wheel, to prevent too much side play or lateral motion.

The driving boxes are placed between the jaws of the frame or pedestal.

177. Shoes are placed between the pedestals and the boxes to prevent wear of the frames.

178. An adjustable wedge is placed between the shoe and the pedestal at the back of each driving box. This wedge can be moved up or down by means of a screw or bolt threaded in and passing through the pedestal cap.

A jamb nut is used to prevent this adjusting bolt from working loose. The lost motion in the driving box is taken up by means of this wedge.

179. An oil cellar is placed under the axle between the jaws of the driving box; this oil cellar is filled with wool waste saturated with oil for the purpose of lubricating the journal. In some cases hard grease is used instead of waste and oil.

180. Each driving box has oil holes bored down through the top and the crown brass. A small amount of waste is laid on top of the box and saturated with oil; the oil feeds gradually through the holes in the box to the journals, assisting in keeping them lubricated.

THE SPRING SADDLE

181. A spring saddle which is placed on top of each driving box astride the frame is used as a support for the driving springs.

THE DRIVING SPRINGS

182. The driving springs are used to modify the amount of shock, which otherwise would be imparted to the frames when the driving wheels run over rough places in the track.

183. The driving springs are made of spring steel, and are made up of a series of leaves or thin flat strips, bound together by a band around the center.

SPRING HANGERS

184. A spring hanger is a bar or bars which connect the ends of the springs with the frame or equalizers.

EQUALIZERS

185. Equalizers are used for equalizing the weight between two or more parts. When the engine truck runs over a rough place in the track a part of the shock is transmitted through the long truck equalizer to the front driving springs.

With engines having trailers, equalizers are used to connect the trailer with the main springs, thus causing the engine to ride easier and reducing the liability of breakage.

ENGINE TRUCKS

186. A truck, the design of which varies according to the style of engine with which it is used, is placed under the forward end of the main frame, for the purpose of guiding the engine and helping to carry the weight.

187. Some trucks have four wheels and are called bogie or engine trucks. This style of truck has a rectangular frame supported by semi-elliptical springs suspended from equalizers, the ends of which rest on the truck boxes. A center plate is placed in the center of the truck frame upon which the front end of the engine is pivoted, and upon which it turns in following the curvature of the track. This style of truck is usually used with engines which are designed to run at a high rate of speed.

188. Another style of truck is a two-wheeled truck, called a pony truck, which carries the weight on a frame which rests on two bearings which are inside the wheels.

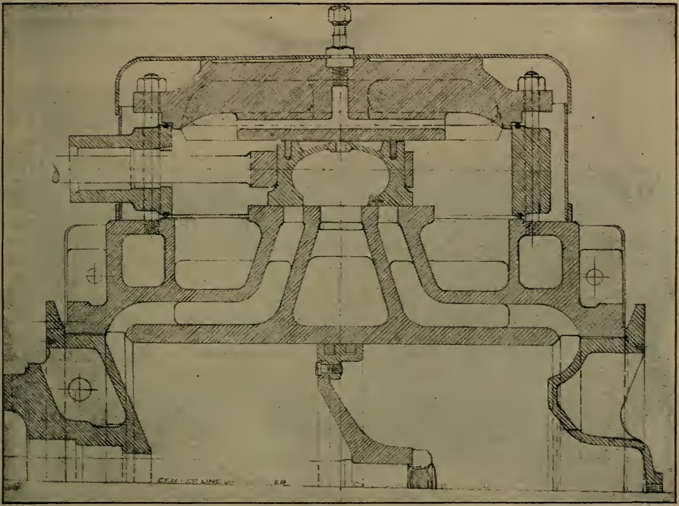


FIG. 3.—Sectional View of Steam Chest, Slide Valve, and Seat.

The front end of the locomotive frame is pivoted on the center of the truck frame.

THE VALVES

189. Valves are used to admit the steam to and exhaust it from the cylinders.

190. There are two kinds of valves which are most generally used. They are the slide valve and the piston valve.

THE SLIDE VALVE

191. The *D* type of balanced slide valves is generally used, although the piston valve is coming into general favor especially in connection with the Walschaert valve gear.

192. The balanced slide valve is shown in Figs. 3 and 4.

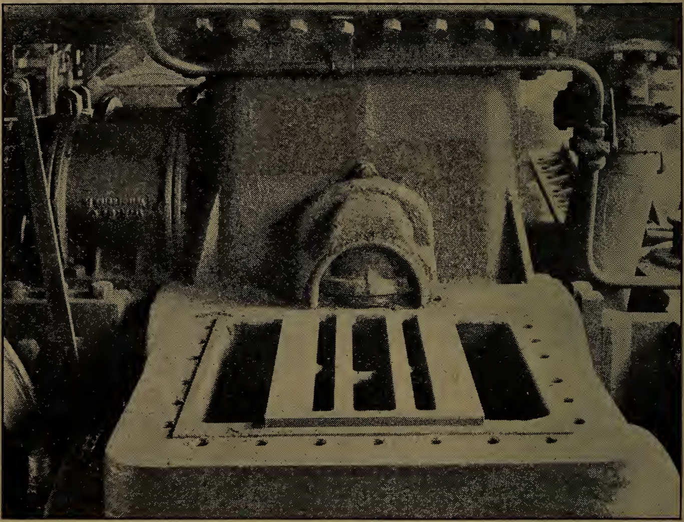


FIG. 3*a*.—Slide Valve Seat and Arrangement of Ports.

It is provided with a large cavity in its face through which the exhaust takes place. On the back of the valve are slots in which are placed balance strips; these strips are held against the friction plate (which is attached to the steam chest cover) by springs placed under them. These balance strips prevent the steam from covering the whole top surface of the valve, thereby relieving it of considerable weight which it would otherwise have to carry.

193. In the construction of the most simple form of slide valve, the edges of the valve are just the same width as the ports which they cover when the valve is central on its seat.

194. With this valve steam is admitted to the cylinder during the full length of the piston's stroke and the steam

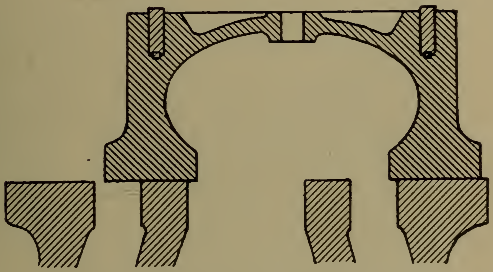


FIG. 4.—Slide Valve Showing Lead.

thus admitted is exhausted during the whole of the return stroke.

195. In order to use the steam expansively slide valves are now made so that the edges of the valve will extend or lap over beyond the edges of the ports when the valve is central on its seat as shown in Fig. 3.

196. When the valve is moved to one side of its central position on its seat, steam is admitted to one end of the cylinder and is exhausted from the other through the cavity in the valve as shown in Fig. 4.

THE ALLEN VALVE

197. The Allen or Allen-Richardson valve is a *D* type of slide valve having a supplementary port cast through it above the exhaust arch.

This supplementary port is for the purpose of admitting steam from both sides of the valve to the same port at the same time and also for the purpose of admitting a larger amount of steam to the cylinder earlier in the stroke than can be done with a common slide valve.

THE PISTON VALVE

198. Piston valves are coming into general use on account of being perfectly balanced in so far as the pressure under which they work is concerned. In general construction they are spool-shaped with spring packing rings around the ends to prevent leakage.

199. They may be either inside or outside admission. By inside admission is meant one which admits steam to the cylinder from around the inside or spindle part of the valve and exhausts it at the outer ends.

200. An outside admission valve is one which admits steam to the cylinder from the outer ends of the valve and exhausts it through or around the inside part of the valve. A piston valve is shown in Figs. 5 and 6.

201. The valve seats are cylindrical in form and the ports in its seat extend completely around the valve. These ports have small braces cast across them for the purpose of strengthening the parts and to prevent the

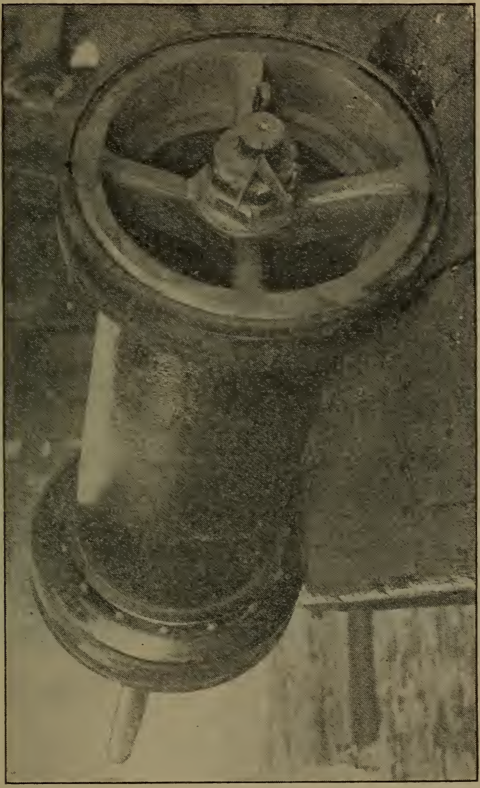


FIG. 5.—Piston Valve.

valve packing rings from catching on the edges of the ports as the valve moves over them.

LAP

202. When speaking of lap, as applied to the valves of a locomotive, we mean that part of the valve which

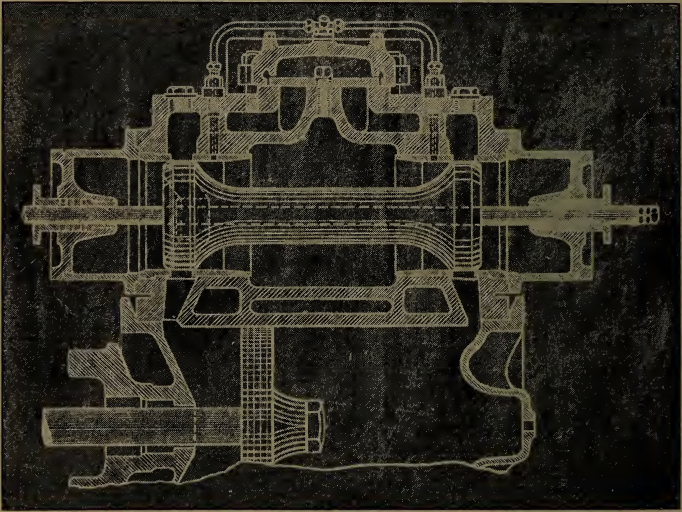


FIG. 6.—Piston Valve and Arrangement of Ports in Steam Chest.

laps over or extends beyond the edges of the ports when the valve is central on its seat.

203. Lap is used for the purpose of cutting off the admission of live steam to the cylinder when the piston has only completed a part of its stroke. The lap of the valve then covers the port holding the steam in the cylin-

der, where it expands, forcing the piston to complete its stroke (this is what is meant by using steam expansively).

204. Outside lap is that part of the valve which laps over on the valve seat on the outside edge of the port when the valve is central on its seat.

205. Inside lap is that part of the valve which laps over on the valve seat on the inside edge of the port when the valve is central on its seat.

206. Inside lap controls the beginning of release and the period of compression. By increasing the inside lap the exhaust is retarded and compression increased. While decreasing the inside lap causes the exhaust to begin earlier. consequently the compression is less. The effects of lap are further explained under the head of valve gears.

LEAD

207. The amount of port opening allowed by the valve for the admission of steam to the cylinder when the piston is at the beginning of its stroke is called the lead.

208. Valves are set with lead for the purpose of allowing a small amount of steam to enter the cylinder at the same time that the piston reaches the end of its stroke. The steam fills up the clearance space and also acts as a cushion to receive the force of the piston, cross-head, and main rod, and ease them over the center and start the piston on its return stroke. By setting a valve with lead it permits of a higher pressure in the cylinder at an earlier point in the piston's stroke than is obtained with a valve set without lead.

209. Authorities on locomotive construction differ as to the necessity for or advantage of lead, but such arguments must not let us lose sight of the real facts, which are: that a weight of several hundred pounds is moving at a high rate of speed and must be stopped and after stopping must be started immediately in the opposite direction. Now if this weight was to come in contact with a spring immediately before coming to the end of its stroke or stopping-point, the velocity of its movement alone without any added force would compress the spring. The spring, while being compressed, would ease the weight to a stop; the spring, being now compressed, exerts all its power against the weight to start it back on its return stroke. This is just what lead does; it acts as a spring to receive the force of the blow being struck by the piston as it is being forced through the cylinder by the live steam behind it.

210. Therefore the necessity for lead is apparent only when there is a high speed movement of the piston.

Because when the piston is at the end of its stroke, and the engine is on its dead center, as in starting a train, full boiler pressure, if admitted into the cylinder against the piston, would not move it. The engine, which is on its center, must be moved off the center line by the engine which is on the quarter, as the engine which is on the quarter is at its strongest point. The valve is giving a full port opening on that side in full stroke, and no advantage can be gained by giving that valve any additional advance movement.

211. When a valve gear is used which increases its lead

when moved from full stroke toward the center, the valves should be set to give one-fourth inch lead when the reverse lever is in the ordinary running position for that class of engine, regardless of the amount of lead which will be obtained at full stroke. With some classes of engines, setting the valves with one-fourth inch lead in running position, will show line and line in full stroke, while others will show from a sixty-fourth to one-eighth blind.

With engines having a valve gear which does not increase its lead, the same rule for setting may be followed, as the advantages derived from the proper amount of lead in running position are greater in proportion than the disadvantages derived from having a slight excess of lead in starting.

VALVE GEARS

212. Motion is imparted to the valves in several ways, by different styles of valve gears. By valve gears is meant the combination of parts which actuate and control the movement of the valve.

213. The Stephenson, Allen, and Walschaert valve gears are the styles generally used by the different roads at the present time.

THE STEPHENSON VALVE GEAR

214. Four eccentric blocks, two for each engine, are placed on the main axle between the main frames. These blocks are round flat discs with a round hole through them, large enough to fit around the main axle. These

holes are placed in the blocks to one side of the center, so that when they are fastened on the axle and the axle is turned, they will impart to the straps in which they work a circular or crank motion.

215. A disc eccentric, such as described above, is simply an improved way of imparting a crank motion to other parts of a machine where, on account of its construction, a crank could not be used. The disc eccentric has some advantages over the common crank by reason of the large bearing surface on the strap in which it works, causing the eccentric to pass the center with less jerk or jar than is imparted by a crank.

216. There being two eccentric blocks for each engine, one is called the forward motion eccentric and governs the forward movement, the other is called the back motion eccentric and governs the backward movement.

217. The distance from the center of the eccentric block to the center of the axle on which it is placed is one-half the throw of the eccentric.

218. The travel of the valve at full stroke will be equal to the throw of the eccentric.

219. The eccentric strap in which the eccentric block works is connected to the link by means of an eccentric rod; the forward motion eccentric rod usually is attached to the top connection of the link and the back motion eccentric rod to the lower connection.

220. The link is a slotted bar curved to the radius of the length of the eccentric rod.

221. By the radius of the eccentric rod we mean the curvature of a complete circle which the end of the rod

would describe if it were turned completely around on the axle.

THE LINK BLOCK

222. A block called a link block is placed in the slot in the link, to which block a transmission bar is attached; the other end of this bar being attached to the lower arm of a rocker shaft, the top arm of which is connected to the valve stem, which, in turn, is connected to the valve in the steam chest by means of a valve yoke.

223. The links are raised or lowered by means of hangers which are connected to a tumbling shaft to which shaft the reach rod and the reverse levers in the cab are connected and by which the length of stroke and position of the valves are controlled.

224. The link being raised or lowered changes the position of the link block in its relation to the ends of the two eccentric rods which are connected to the link.

225. When the link block is opposite the end of the forward motion eccentric rod, the valve will travel its full stroke, but as the link is raised and the eccentric rod is moved away from the link block and the center of the link is brought nearer to the block, the valve travel will be shorter.

THE SADDLE PIN

226. The saddle pin, by which the link is suspended, is set out of center on the link so that the cut-off of the valve will be equal at half stroke.

227. The cut-off—by which is meant the point at which

the valve cuts off the admission of live steam to the cylinders at certain points of the piston stroke.

228. When the link block is at either end of the link, the cut-off will take place near the end of the piston's stroke. As the link is moved so that the block will be near the center of the link, the cut-off will occur earlier in the stroke.

229. With the Stephenson valve gear the lead of the valve increases as the valve travel is shortened. This is caused by the increased angularity of the link block to the center line of motion of its controlling eccentric and because the link block is so near to the center of the link that its movement is influenced by the opposite motion eccentric.

THE SLIDE VALVE OPERATED BY THE STEPHENSON VALVE GEAR

230. When the main pin is on the forward center in the forward motion, the forward motion eccentric is on top of the axle or nearly so, being set forward toward the pin just the amount of the lap plus the lead.

231. The amount which the eccentric is advanced on the axle toward the pin from its position of 90 degrees, or the fourth part of a circle behind the pin, is called the angular advance of the eccentric and is used to offset the lap and lead given the valve.

232. If the valve had no lap or lead the eccentric would be set at exactly 90 degrees behind the pin and would not be given any angular advance.

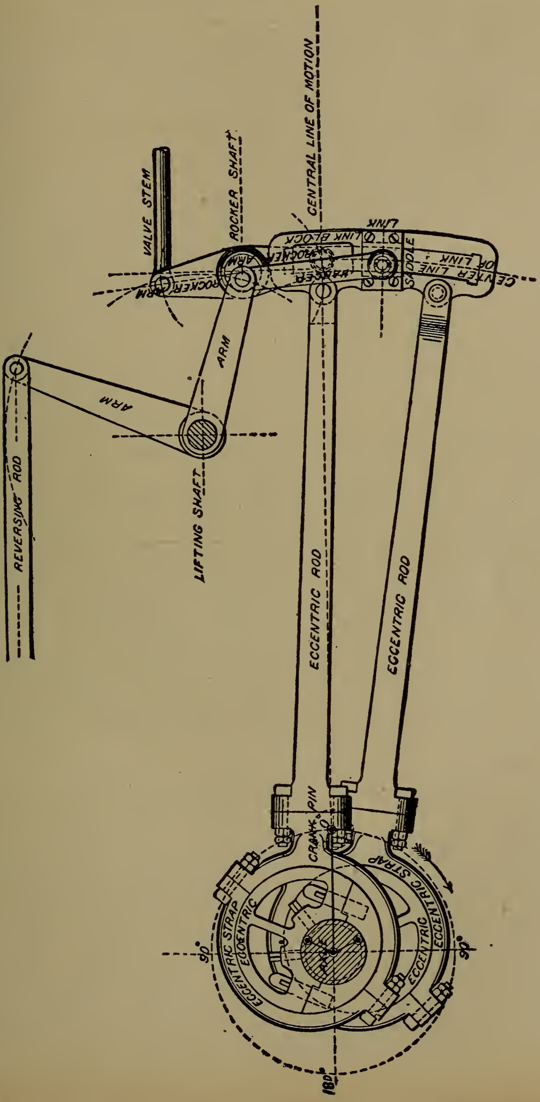


FIG. 7.—Stephenson Valve Gear.

233. The back motion eccentric bears the same relation to the pin when the pin is on the back center in the backward motion that the forward motion eccentric bears to the pin when in the forward motion.

234. The main pin being on the forward center, the eccentric in moving over the top of the axle has thrown the top of the link forward, imparting the same forward motion to the radius rod and lower arm of the locker shaft, throwing the top arm of the rocker shaft back, moving the valve back just the amount of the lap, plus the lead, or just the amount of the angular advance of the eccentric.

235. The steam, now admitted to the cylinder by the lead of the valve, just as the piston reaches the end of its stroke, acts as a cushion, easing the piston over the center and starting it on its return or backward stroke, forcing the pin toward the bottom quarter, as the eccentric always follows the pin. It is now moving the top of the link still farther forward, transmitting the same forward motion to the radius rod and lower rocker arm and moving the top arm and valve back. This motion continues until the pin has reached a point near the bottom quarter, the exact point depending on the point of cut-off; the valve has now traveled its full stroke, opening the forward steam port wide open. As the piston is still traveling back, forcing the pin past the bottom quarter, the motion of the valve begins to change. The eccentric, having passed the forward center, begins to pull the top of the link back, moving the radius rod and lower rocker arm back and moving the top arm and valve forward. This motion continues until the pin has passed a short distance beyond

the bottom quarter when the lap of the valve closes the steam port, shutting off the admission of steam to the cylinder. This is known as the point of cut-off.

The valve now covers the steam ports and the steam which was admitted to the cylinder is shut in; this steam expands, forcing the piston to the end of its stroke.

As the pin nears the back center the eccentric is passing the bottom quarter, moving the top of the link radius rod and lower rocker arm back, and moving the top arm and valve forward far enough to overcome the lap and admit lead at the rear of the valve just as the piston reaches the end of its backward stroke.

The exhaust cavity in the valve is now moving over the forward steam port, exhausting the steam which was admitted during the backward stroke of the piston.

236. When the engine is reversed the backward motion eccentric, which is connected to the bottom connection of the link, controls the valve, the action of the parts being just the same as for the forward movement.

237. The point of cut-off and direction of motion are controlled by the position of the reverse lever.

THE ALLEN VALVE GEAR

238. The Allen valve gear is made with a straight link and the eccentric rods are connected to the link just opposite to that of the Stephenson valve gear; the forward motion eccentric rod being connected to the bottom of the link and the backward motion eccentric rod to the top of the link.

239. When the engine is in the forward motion, the links will be up with the link block at the lower end of the link.

240. The valve motion is reversed by moving the link block as well as the link, the link block being moved about

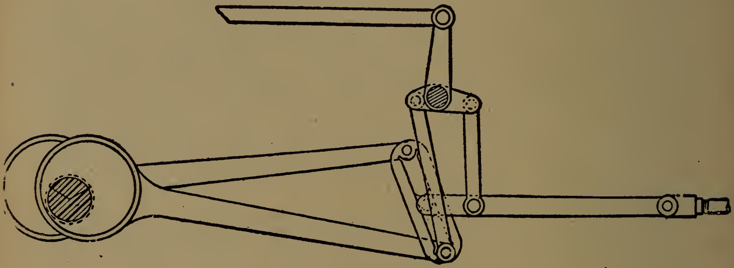


Fig. 8.—Allen Valve Gear.

two-thirds and the link one-third of the distance necessary to make the change desired. (See Fig. 8.)

241. The Allen valve is not essentially a part of this gear, although it may be used in connection with it if desired.

THE WALSCHAERT VALVE GEAR (Fig. 9)

The Walschaert valve gear, which is coming into general use, having been adopted as the standard by a number of roads in this country, has been in use for a number of years in England and other foreign countries.

This style of valve gear possesses some very important advantages over the old styles.

242. One of its most important features is that it is

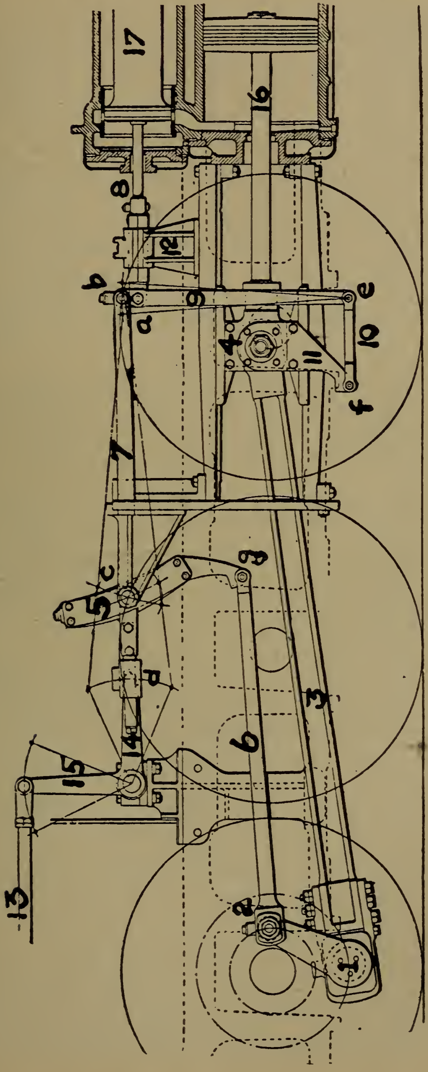


FIG. 9.—Walschaert Valve Gear.

open to the view where all of its parts can be readily seen and its defects discovered. It is light, accurate, and durable. The cost of repairs is much less than the old styles of valve gears.

243. Its parts, their names, and relations to each other in controlling the valve, are as follows: The eccentric crank, the eccentric rod, link, link block, radius rod, combination or lap and lead lever, union link, cross-head arm, valve stem guide, lifting link, lifting arm, reversing shaft and arm, reach rod and reverse lever.

244. With this style of valve gear a link is used which oscillates on trunnions placed in the center of either side of a bracket which is bolted to and supports the link.

245. The link is curved to the radius of the radius rod, with the engine on either forward or back center; the reverse lever can be moved from one end of the quadrant to the other, raising and lowering the radius rod and link block without moving the valve or the link.

246. When the engine is reversed, the link block is raised or lowered while the link remains stationary.

247. The amount of movement imparted to the valve by the movement of the reverse lever will depend on the position of the main pin. If the pin is on either dead center there will be no movement of the valve, but if on any other point the valve will be moved by any change in the position of the reverse lever.

248. The combination or lap and lead lever to which the radius rod and valve stem are attached, the lower end of which is connected to the cross-head by a cross-head arm and union link, controls the movement of the valve

just the amount of the lap plus the lead at each end of the valve stroke, this movement being independent of the eccentric rod and link.

249. If the reverse lever is placed in the center of the quadrant the link block will be in the center of the link; in this position the movement of the link by the eccentric will not transmit any motion to the radius rod or valve, but the combination lever, being attached to the cross-head, will move the valve just the amount of the lap plus the lead.

250. With an outside admission valve the eccentric crank on the main pin will lead the pin in the forward motion, being set on the quarter or 90 degrees ahead of the pin.

251. With an inside admission valve the eccentric crank will follow the pin in the forward motion, being set on the quarter or 90 degrees behind the pin.

252. The position of the eccentric crank in its relation to the pin is sometimes changed from the positions just described in order to overcome or equalize the angularity of the eccentric rod. When the extension on the bottom of the link is shortened it carries the forward end of the eccentric rod away from the center line of motion, causing an unequal angularity of the eccentric rod, from its position on the top and bottom quarters and its connection to the link extension. Therefore in order to make the construction theoretically correct the eccentric crank would have to be moved to a position a little over 90 degrees back of the pin with an inside admission valve and moved toward the pin from its

position of 90 degrees ahead of the pin with an outside admission valve.

253. With the cross-head and piston in the center of their stroke the main pin will not be on the exact quarter line. This offset of the pin is occasioned by the angular position of the main rod. By disconnecting the butt end of the rod from the pin, and raising it up to the center of the main axle it will show, in the exact center of the pin bearing, the distance between the center of the pin and the quarter line will be the distance necessary for the cross-head and piston to travel beyond the center of their stroke to place the pin on the quarter.

254. It is not necessary to make any change in the adjustment of the Walschaert gear, to offset this angularity of the main rod, because this variation of the motion occurs only when the eccentric crank is at either center; while in this position the rear end of the eccentric rod could be raised or lowered for a considerable distance without affecting the movement of the valve to any perceptible extent.

DIRECT AND INDIRECT MOTION OF THE WALSCHAERT VALVE GEAR

255. With the reverse lever in the forward position, the link block will be below the center of the link so that the eccentric rod, radius rod, and valve move in the same general direction. This movement causes the engine to be direct in the forward motion.

256. When the engine is reversed and the reverse lever

is in the backward position the link block is raised above the center of the link; the eccentric rod will move the lower end of the link forward, and the top end back, drawing the radius rod and valve back with it and causing the eccentric rod and valve to move in opposite directions. This movement causes the engine to be indirect in the back motion.

257. With an inside admission valve the radius rod is connected to the combination lever above the valve stem so that when the cross-head reaches the end of the stroke the valve may be drawn back the amount of the lap plus the lead.

258. As the motion of the cross-head is always the same, and an outside admission valve is used, the radius rod would be connected below the valve stem. A valve stem support or guide is provided for the purpose of carrying the weight of the front end of the radius rod and combination lever and to keep the valve stem from being thrown out of line by the weight of its connection.

RELATIVE POSITIONS OF THE VALVE, MAIN PIN AND ECCENTRIC OF THE WALSCHAERT VALVE GEAR WITH INSIDE ADMISSION VALVE

259. When the main pin is on the forward center in the forward motion the eccentric crank will be on the top quarter or 90 degrees behind the main pin. As the lap and lead or combination lever has already moved the valve forward the amount of the lap plus the lead steam

is now being admitted to the front end of the cylinder, pushing the piston back, and moving the main pin toward the bottom quarter.

The eccentric crank moves toward the forward center, moving the bottom of the link, radius rod, and valve forward and opening the front steam port wide.

As the main pin passes the bottom quarter the eccentric will be passing the forward center and is now beginning to pull the bottom of the link radius rod and valve back.

The combination lever is now assisting to move the valve in order to take care of the advance necessary to overcome lap and produce lead; this causes cut-off to take place (the exact point of cut-off is determined by the position of the reverse lever).

The valve now covers the ports, shutting the steam in, and causing expansion which lasts until immediately before the pin reaches the back center, when exhaust takes place.

The eccentric is now on the bottom quarter, the main pin on the back center, the cross-head and piston at the back end of the guides and cylinder; the combination lever has now moved the valve back, admitting steam to the rear side of the piston-head to begin the return stroke.

If the engine is now reversed by placing the reverse lever in the backward motion, the link block will be raised above the center of the link. The eccentric will lead instead of follow the pin, the engine will move backward instead of forward, and the movement of the valve will be just the same as if the engine were moving forward.

This movement is accomplished by reason of the fact that the motion is changed from direct to indirect motion by raising the link block above the center of the link.

The position of the engine is such that steam must be admitted to the rear side of the piston to force it to the other end of its stroke, no matter whether the main pin moves over the top quarter or the bottom quarter to reach the forward center.

With the pin on the back center and the eccentric on the bottom quarter in the forward motion, the valve would be admitting lead steam to the cylinder behind the piston. Now place the reverse lever in the back motion, the link block above the link center; the curvature of the link being the same as the radius of the movement of the link block, the position of the valve is not changed and the valve continues to admit lead steam behind the piston just the same as before the engine was reversed.

The engine being on its dead point cannot move itself either way, so it depends on the other engine which way it will move from its dead point. In this case the opposite engine is moving backward. This moves the main pin of the engine which is on the center or dead point toward the bottom quarter; the eccentric crank moves toward the forward center, moving the lower end of the link forward, the top of the link back pulling the radius rod and valve back with it, opening the back steam port, causing the valve to describe the same movement as if the engine had remained in the forward motion; the main pin would have moved over the top quarter to the forward center, but being reversed, caused the main pin to move over the bottom quarter to reach the forward center, and that difference is really what caused the engine to move backward instead of forward.

260. The constant lead of the Walschaert valve gear is obtained by connecting the valve stem and radius rod to the top of the combination lever and attaching the lower end of the combination lever to the cross-head, the cross-head moving back and forward in the guides transmits an angular position to the combination lever. This angularity is greatest when the cross-head and piston are at the end of the stroke at this point. The difference between two perpendicular lines drawn through the centers of the pins connecting the radius rod and valve stem to the combination lever will show the same measurement as the lap of the valve plus the lead. For this reason the lead does not vary with the point of cut-off as it does with the Stephenson valve gear, but remains constant at all points of the stroke.

VALVE SETTING

261. Valve setting is essentially a machine-shop practice, but every engineer should have enough general knowledge of the subject to enable him to set the valves if it should become necessary for him to do so.

262. To set the valves with the Stephenson valve gear and balanced slide valve, place the engine on the forward center with the reverse lever in the full forward position. To find the exact center, place a mark on the cross-head and guide opposite each other, just before the cross-head reaches the end of its stroke. With a center punch place a punch mark on the frame just in front of the main

driving wheel; place one end of the tram in this punch mark and with the other end of the tram make a mark on the rim of the wheel. Now move the engine forward until the cross-head has passed the center and moved back until the marks on the cross-head and guide are again opposite each other. Now with the tram placed in the same punch mark on the frame as before, make another mark on the rim of the wheel; with a pair of dividers divide the space between the two marks. This will give the exact dead center. Now with the tram in the punch mark on the frame, move the wheel until the other end of the tram will rest in the center punch mark. The engine is now on a dead center. Move the eccentric block forward toward the pin from its position of right angles until the valve has moved back the amount of the lap and has given the desired opening for lead. The eccentric block should be keyed fast at this position on the axle. The back motion eccentric can be set in the same manner. Care must be taken to place the reverse lever in full gear ahead when setting the forward-motion eccentrics and in full gear back when setting the back-motion eccentrics. The engine should always be moved in the direction of movement controlled by the eccentric being set.

Should the lead not be equal at both ends of the stroke, correct the defect by changing the length of the valve yoke stem one-half and the angularity of the eccentric one-half of the distance necessary to cause the lead to be even. If the valve travel should become unequal or get out of square, as this condition is sometimes called, the parts should all be examined very carefully for lost motion, loose nuts, bolts, or broken parts. If no defects are discovered, then tram the valve travel. If the valve travels more to the front of the center line than to the rear, lengthen the eccentric rod. If the valve travel is too much to the rear, shorten the eccentric rod. In order to determine accurately just the required amount to lengthen or shorten the eccentric rod, place the valve central on its seat; now with a tram placed against the cylinder casting, mark the valve stem; now move the engine slowly until the valve is at the extreme point of travel with the tram, in the same position as before; place another mark on the valve stem; now move the engine until the valve has moved to its extreme point of travel in the opposite direction; with the tram place another mark on the valve stem. The three marks made by the tram on the valve stem will represent the center line of the valve and the valve seat. The forward mark will represent the extreme backward travel of the valve, the rear mark will represent the extreme forward travel of the valve.

The difference in the distance between the forward mark and the center and the rear mark and the center, is the amount of unequal travel of the valve.

To test the travel of the valve in the backward motion, place the reverse lever in the full backward position and proceed as before.

In order to test the accuracy of the work, the reverse lever should again be placed in the full forward position and another test of the valve travel made. After the length of the eccentric rods has been changed so as to correct the defects of the valve travel, the valves should again be run over to see that the change has been made correctly.

263. To set the valves with the Walschaert valve gear, place the engine on the forward center; to find the exact center, proceed in the same manner as explained for finding the exact dead center with the Stephenson valve gear. After placing the engine on its forward dead center, proceed as follows: Move the reverse lever from full forward position to full backward position; if there is any movement of the valve forward while raising the block in the link, the eccentric rod should be lengthened, if there is any movement of the valve backward the eccentric should be shortened.

After the eccentric rod has been adjusted to the proper length, now tram the valve travel. If it does not travel the same distance on either side of the center line of the valve seat, adjust the difference by lengthening or shortening the valve stem.

There are some classes of engines equipped with the Walschaert valve gear that have an adjustable valve stem connection, but on account of the adjustment nuts working loose and stripping their threads, they are being taken off and key connections are now being used.

264. The different parts of the Walschaert valve gear are of a pre-determined size, length, and movement, and under ordinary conditions are not subject to change, but when absolutely necessary the eccentric rod or valve stem may be adjusted to correct defects in link or valve travel.

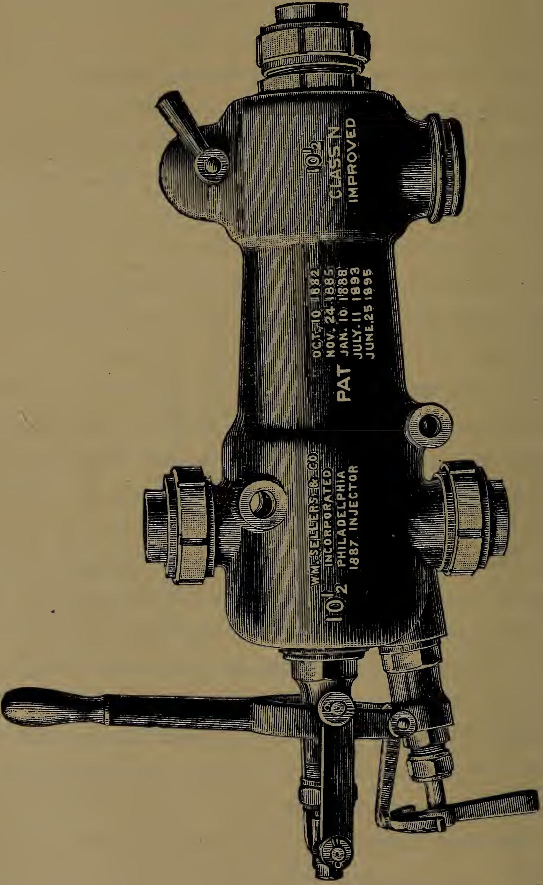


Fig. 10.—Sellers Injector.

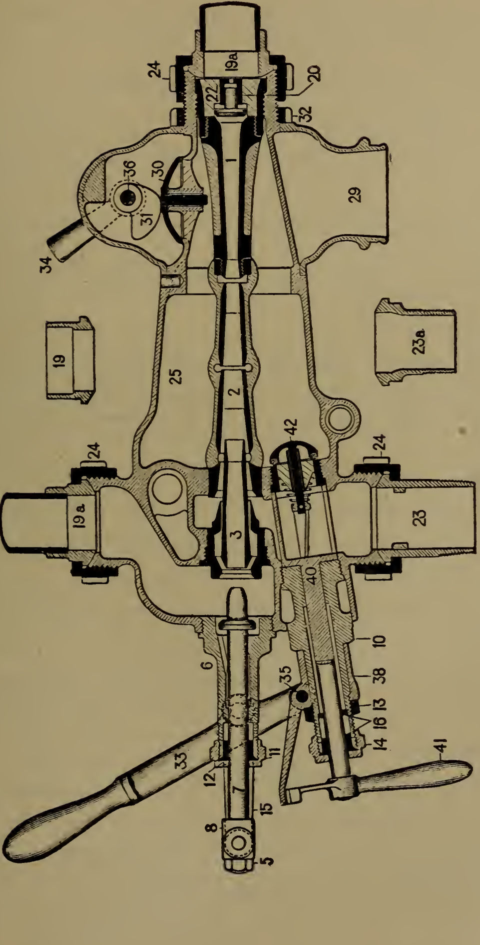


FIG. 11.—Sellers Injector, Sectional View.

INJECTORS

265. Injectors are used for supplying water to the boiler from the tank.

266. They are either lifting or non-lifting.

267. A lifting injector is one which is placed on the boiler above the water line in the tank and raises its supply by suction.

268. A non-lifting injector is one that contains no lifting tubes and is placed on the boiler below the level of the floor of the tank, so that the water will flow into it from the tank by gravity.

269. In general construction, injectors have a water supply pipe, 23, Figs. 10–11, connected to the water space in the tank. A valve, 40, is placed in this pipe to regulate the supply.

270. A large steam pipe is connected to the injector at 19, and to the spider from which dry steam is taken to operate the injector.

271. The delivery or branch pipe, 19*a*, is connected to the barrel of the injector and the boiler.

272. A check valve, 20, is placed in the end of the pipe to prevent the boiler pressure from flowing back through it.

273. The names of the parts of the injector are as follows:

1 Delivery tube.
2 Combining tube.
3 Steam nozzles.
5 Spindle nut.
6 Steam stuffing.
7 Spindle.
8 Cross-head.
10 Water stuffing box.

11 Follower.
12 Packing ring.
13 Lock nut.
14 Follower nut.
15 Links.
16 Packing ring.
19 Steam pipe connection.
20 Check valve.
22 Guide for check valve.
23 Union for pipe.
24 Coupling nuts.
25 Injector body.
29 Waste pipe.
30 Waste valve.
31 Waste valve cam.
32 Jam nut.
33 Starting lever.
34 Cam lever.
36 Cam shaft.
38 Collar and index.
40 Plug water valve.
41 Regulating handle.
42 Inlet valve.
57 Overflow connection.

TO OPERATE THE INJECTOR

274. To operate the injector pull out the starting lever to which the steam spindle is connected just far enough to break the joint and admit steam to the lifting tube; this raises the water into the injector, causing it to flow out through the overflow valve (this is called priming), then pull starting lever wide open. The large amount of steam thus admitted will force the water forward into the combining tube, where the steam from the boiler combines with the water from the tank and together are forced by the velocity of the dry steam supply and the induced current caused by the union of the steam and water into the delivery tube.

275. The velocity of the water when expelled from the injector into the branch pipe causes it to have a penetrating force much greater than the resistance of the steam and water in the boiler. It is this velocity which causes the boiler check valve to raise and the water to enter the boiler.

276. The theory of injector action is the subject of much discussion.

Some authorities hold that the water is forced through the branch pipe and into the boiler by the pressure of

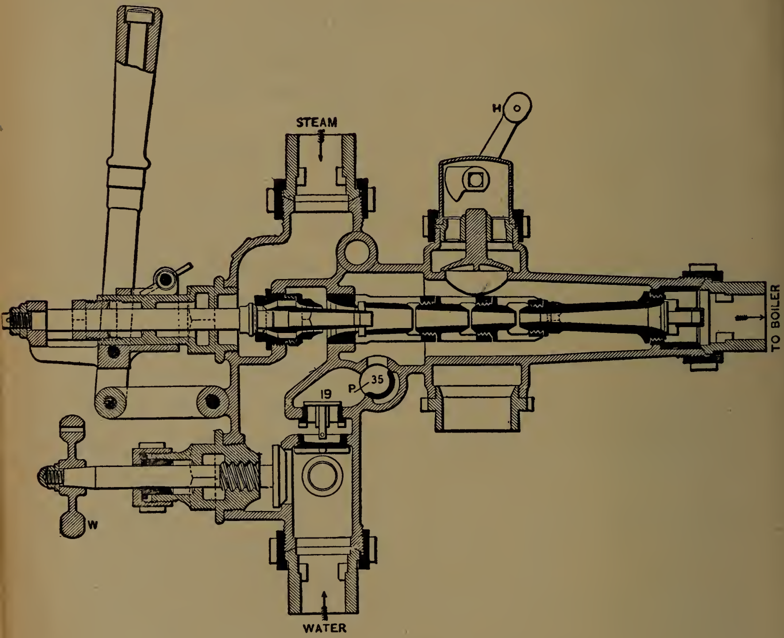


FIG. 12.—Simplex Injector, Sectional View.

steam directly against the solid water in the combining chamber. Other authorities hold the more generally accepted theory that the water is forced into the boiler by the velocity of the steam in passing through the injector from the boiler and the induced current caused by the

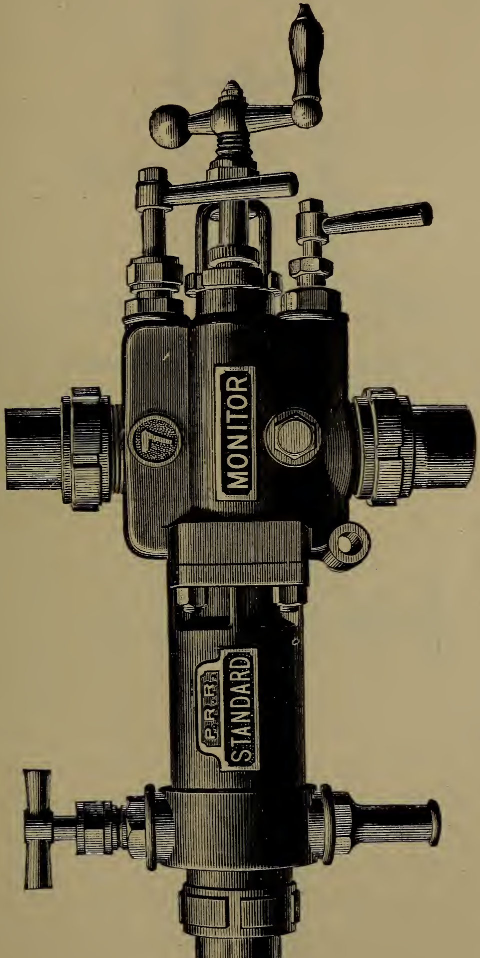


FIG. 13.—Monitor Injector.

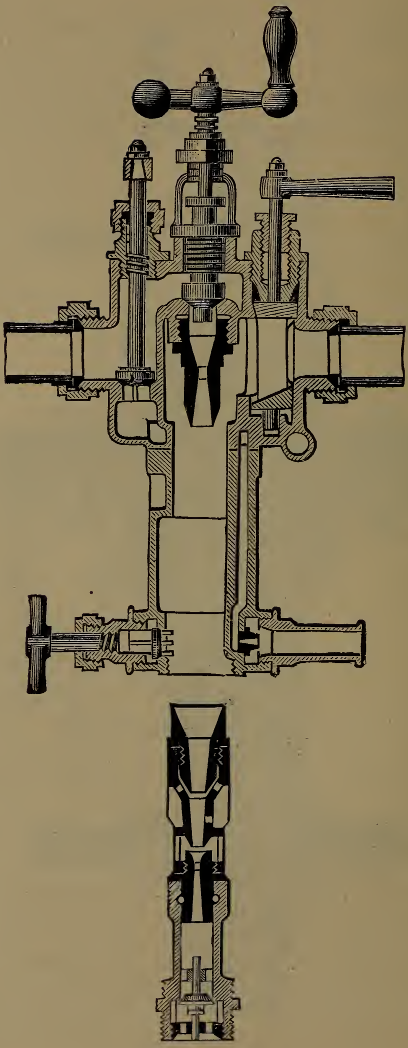


Fig. 14.—Monitor Injector, Sectional View.

union of the steam and water in the injector. The theory of velocity and induced current seems to be the most practical.

277. Water is usually supplied to the boiler at a point as far away from the fire-box as possible, to prevent the sudden contraction and expansion of the fire-box sheets.

278. Some classes of locomotives have the injectors placed on the boiler head with the branch or delivery pipe connected to the boiler on the boiler head just above the crown sheet. The delivery or branch pipe in this case is extended forward to the front end of the barrel, delivering the water at the same distance from the fire-box as if the branch pipe had been carried forward on the outside and attached in the usual manner to the forward end of the barrel.

INJECTOR DEFECTS

279. The supply pipe and its connections must be absolutely air-tight with lifting injectors, because the water is raised to the injector by steam which passes through a lifting tube, causing a vacuum in the water chamber in the injector and upper end of the supply pipe.

280. The air pressure on the water in the tank forces the water up into the injector to supply the vacuum.

281. When an injector fails, and the cause is not known, look in the tank to see if there is plenty of water; then see if the tank valve is open and the supply hose and strainer are clean, that there are no leaks in the supply pipe or its connections, and that the overflow valve is open.

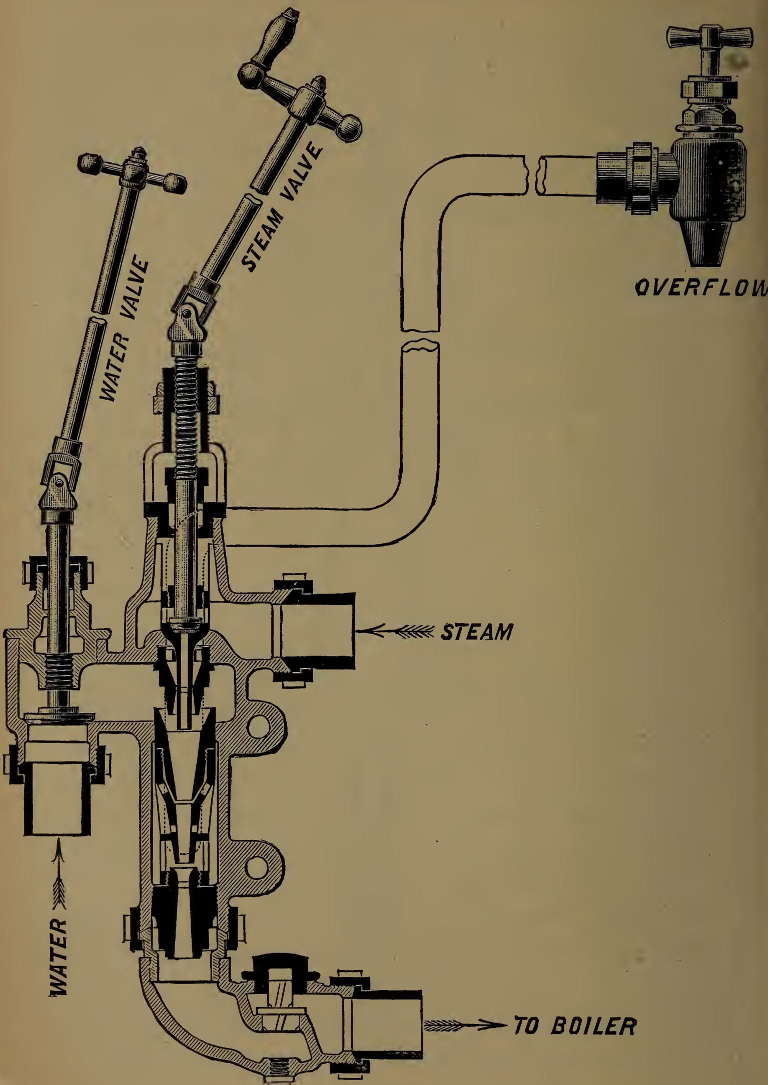


Fig. 15.—Non-Lifting Injector, Sectional View.

282. If the injector still refuses to prime or lift the water, it may be on account of the injector being overheated, causing the water rising into it to become vaporized so quickly as to force the water back into the pipes.

If the injector has a regulating supply valve, be sure it is open, admitting water to the injector. If the injector still refuses to lift, the trouble must be in the steam supply or in the lifting tube.

283. Should the injector prime all right but refuse to force water into the boiler, this may be caused by a partly closed tank valve, a collapsed hose, or leakage in the supply pipe which would reduce the supply of water below the quantity necessary to condense all of the steam. This would result in the vacuum being destroyed, allowing the water to pass out through the overflow. Badly corroded tubes, defective tubes, broken line check or a stuck boiler check may cause the same effect.

284. Sometimes the injector will seemingly be working all right but will be spilling water at the overflow. This is usually caused by the water supply being too great for the steam supply. Badly worn tubes or leaks in the supply pipe or any obstruction in the delivery tube will cause the same results. It is necessary at all times to have atmospheric air on the water in the tank. If the tank was made air-tight there would be no pressure on the top of the water to force it up to supply the injector, and as a result the injector would not work.

TO USE THE INJECTOR AS A HEATER

285. To use the injector as a heater open the water supply valve wide and close the overflow valve with the cam; now shut off the steam valve and open the starting lever wide; now just break the steam valve joint which will allow a small quantity of steam to pass from the boiler through the injector, supply pipe, and hose to the tank. The frost or drain cock in the branch pipe should be opened to allow the water and condensed steam to drain out, otherwise the steam will not circulate through this pipe and it is liable to freeze up in cold weather.

286. To shut off heater, to use injector, first close the steam valve, then open overflow and close starting lever; now open steam valve wide and injector is ready for use.

287. In order to keep both injectors in good condition and ready for use, the left injector should be operated quite frequently to insure its being in condition to work if needed in case of emergency.

288. Never leave a terminal, to go on a trip, without examining both injectors to see that they are in proper working condition.

INJECTORS LEAKING STEAM AT OVERFLOW

289. Injectors often leak steam at the overflow; this may be caused by the boiler check valve leaking or by the steam spindle leaking.

290. To test which of these two are causing the trouble,

close the injector steam valve tight and if steam still appears at the overflow it is the boiler check leaking, but if the steam stops blowing at the overflow when the steam valve is shut off then it is the steam spindle.

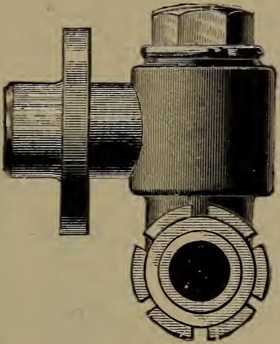


Fig. 16.—Boiler Check Valve.

TO TEST FOR LEAKS IN THE SUPPLY PIPE

291. Close the tank valve and the overflow valve. Now open starting lever just a little, the same as if priming the injector; the steam which is forced back into the supply pipe will force the water in the pipe to appear at the leaks, which can then be tightened or repaired.

LUBRICATORS

291*a*. Lubricators are used for supplying oil to the valves, cylinders, and air pumps.

292. In general construction lubricators are hollow castings having a chamber, *A* (as shown in Fig. 17), to contain the oil.

Attached to the top of the main body of the lubricator is a condensing chamber, *F*. To the top of the condensing chamber is connected a steam-supply pipe the opposite end of which is connected to the spider.

Sight feed glasses are provided either through or on the sides of the lubricator.

Feed valves, as shown at *E.L.E.*, are attached to the lower ends of the sight feed glass; brackets to regulate

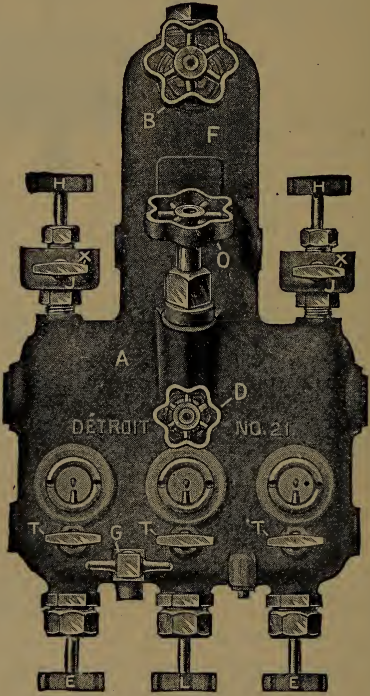


FIG. 17.—Detroit Lubricator, Front View.

the feed through them to the cylinder, pipes called tallow pipes, are connected to the top of the sight feed brackets and to the top steam chests and the steam pipe to the air pump.

293. When steam is admitted into the condensing chamber by opening valve *B*, it soon cools, so that the chamber will be filled with water.

294. The condensing valve, *D*, when opened, will allow the water from the condensing chamber to flow into the oil chamber.

295. As the oil will always float on top of the water it forces the oil to the top of the bowl where it enters open-ended pipes which conduct it to the feed valves *E.L.E.*, at the bottom of the sight feed glasses. When the feed valves *E.L.E* are opened the oil flows drop by drop through the glasses which are filled with water. The oil then passes through the tallow pipes to the cylinders.

296. Some lubricators have equalizing pressure pipes connected to the top of the condensing chamber and to the ends of the tallow pipes at the lubricator connections. Steam passes from the boiler through these equalizing pipes to the tallow pipes, carrying the oil through the tallow pipes and helping to offset the back pressure against which the lubricator works, causing it to feed more regularly.

NAMES OF DIFFERENT PARTS OF THE LUBRICATOR AS SHOWN IN FIG. 17

297. *a*, oil bowl; *f*, condensing chamber; *o*, filling plug; *g*, drain valve; *ee*, feed valves to steam chest and cylinders; *l*, feed valves to air pump; *t t t*, sight feed glass drain valves; *x x*, auxiliary oil cups; *h h*, hand oiler valves; *j j*, auxiliary oil cup valves.

The illustration, Fig. 18, shows a sight feed glass with packing and follower nut.

LUBRICATOR DEFECTS AND REMEDIES

298. Lubricators are sometimes very erratic in their action and must be operated exactly according to directions.

299. If the sight feed glasses become stopped up, open

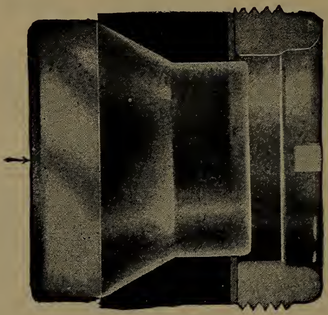


Fig. 18.—Sight Feed Glass and Fittings for Detroit Lubricator.

drain valve *T*, at the bottom of glass, and draw all the oil and water out of them; then close the valve and allow the glasses to fill with water. After the glasses have become completely filled with water the feed valves may then be opened.

300. The feed valve nipples sometimes become stopped up with sediment in the oil. When this occurs drain the oil out of lubricator and leave drain valve open; then open feed valve wide. Now open engine throttle. The back

pressure from the steam chest will sometimes blow the obstruction out of feed nipple into the bowl of lubricator and out at the drain valve. If the obstruction cannot be removed in this way take the nipple out and clean it.

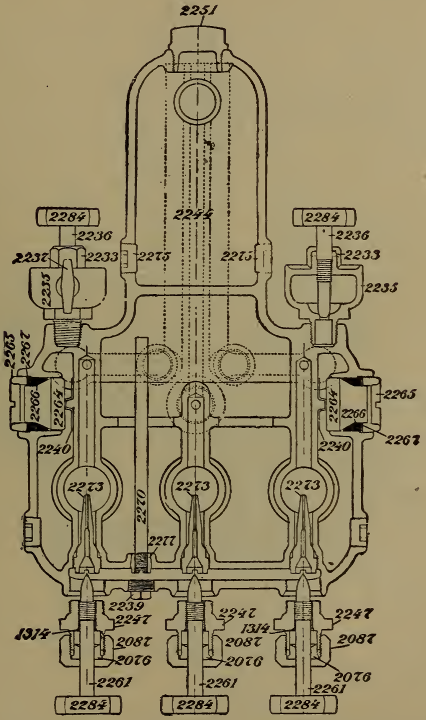


Fig. 19.—Detroit Lubricator, Front Sectional View.

301. The bowl of lubricator should be thoroughly blown out with steam pressure at frequent intervals so as to remove any scale or sediment that may gather in it.

302. The most frequent cause of erratic action in the lubricator is the choke plugs being worn, or filled up with scale or sediment.

303. There are two kinds of choke plugs: one having a

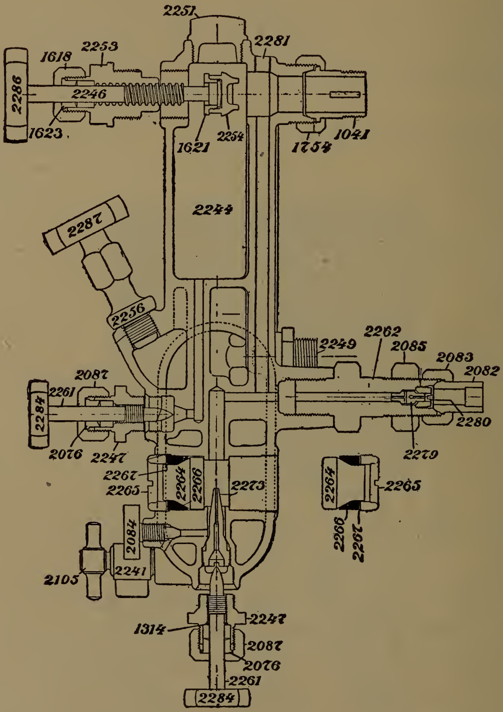


Fig. 20.—Detroit Lubricator, Side Sectional View.

valve in it as shown in Figs. 23 and 24; while the other kind simply has a small hole about the size of a needle drilled through it. Should this hole become stopped up, the lubricator will continue to feed until the tallow pipe is filled up, but the valve and cylinder will get no oil, and the first warning the engineer will have of this condition is

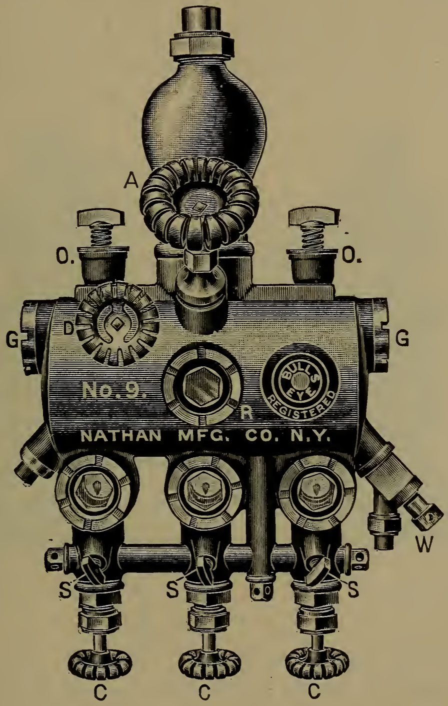


FIG. 21.—Nathan Bull's Eye Lubricator.

when the valves and cylinder become dry. This trouble is seldom experienced with the ball valve plug.

304. It has become the practice on most roads to take the choke plugs away from the lubricators, where they were

formerly located, and place them on the steam chest. This subjects the choke plug to the heavy vibration of the live steam in the steam chest; this vibration is much greater at the steam chest than it is at the lubricator, because the vibration would not travel the length of the tallow pipe and exert the same power and wearing force that it exerts at the steam chest. Because of this con-

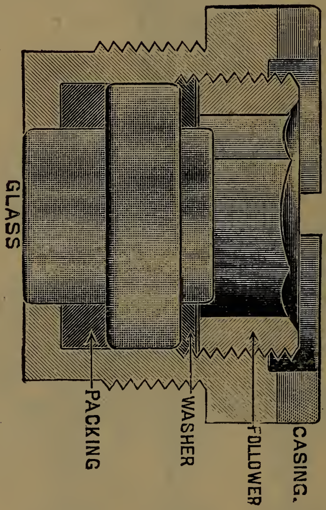


FIG. 22.—Sight Feed Glass and Fittings for Nathan Lubricator.

dition, the choke plugs quickly become worn to a larger size than they should be, if the lubricator feed valves are opened and set to feed at the proper rate when the engine is not using steam, and the throttle is then opened admitting steam to the steam chest the feed becomes slower and where the choke plug is badly worn will stop altogether. This condition works both ways. If the feeds are set while the engine is working steam, and the throttle is then shut off, the feed will increase, and if not regulated will soon drain the lubricator.

This condition is very annoying to the engineer and ex-

FIG. 23.—Choke Valve.

FIG. 24.—Choke Valve, Sectional View.

pensive to the company. Whenever this condition occurs report the choke plugs.

Care should be exercised in the handling and operation of the lubricator.

305. After filling the lubricator, the condensing valve should be opened at once, because the oil in the bowl will expand with the increased heat and if the condensing valve is closed the expanding oil is liable to burst the lubricator.

306. When it becomes necessary to fill a lubricator on the road and it is desired to have it operate as quickly as possible, place the amount of oil desired in the bowl and fill up with water. This will cause the lubricator to start

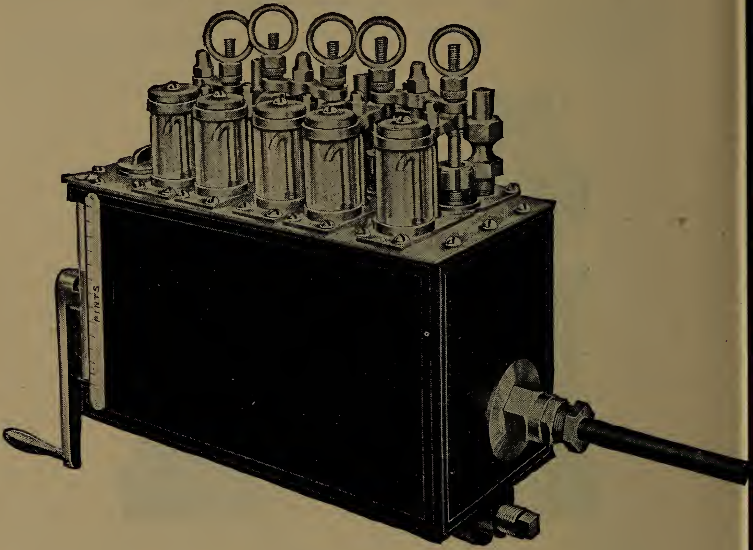


Fig. 25.—McCord Force Feed Lubricator.

to feed immediately after the steam and condensing valves are opened.

THE McCORD FORCE FEED LUBRICATOR

The McCord force feed lubricator differs greatly from other makes of lubricators not only in construction and operation, but in theory of its application as well.

307. In general construction the lubricator has a reservoir to contain the oil. In this reservoir is placed a series of double plunger pumps.

308. The pumps are operated by means of an eccentric rotated by a transformer, which, in turn, is operated by suitable connections to the rocker arm or valve stem.

309. Referring to Fig. 27, the names of the different parts of the lubricator are as follows: *A*, reservoir; *B*, eccentric; *C*, eccentric rod; *D*, *G*, *H*, *K*, and *L* are ball check valves; *E* and *F* are pump plungers; *I*, delivery nipple to sight feed glass; *V*, sight feed glass; *J*, oil passage from sight feed glass; *P*, cross-head; *Q*, pump plunger adjustment nut; *M*, delivery pipe; *N*, terminal check; *O*, gravity valve; *R*, delivery passage; *X*, oil screen.

310. To fill the lubricator, pour the oil into the reservoir through filling screen at *A*.

EXPLANATION OF OPERATION

311. When eccentric *B*, Fig. 27, is rotated in either direction, the eccentric rod *C* is moved upward; this in turn moves the plunger *F* upward, drawing oil through the screen *X*, and above the ball check *G*, rotating the eccentric *B* still farther. The plunger *F* is driven downward, forcing oil past the ball check *H*, and out at point *I*, from where it drops through the sight feed *V*.

As the plunger *E* moves upward, oil is drawn through the passage *J* (shown in dotted lines), from the sight feed and above the ball check *D*; then, as plunger *E* is driven

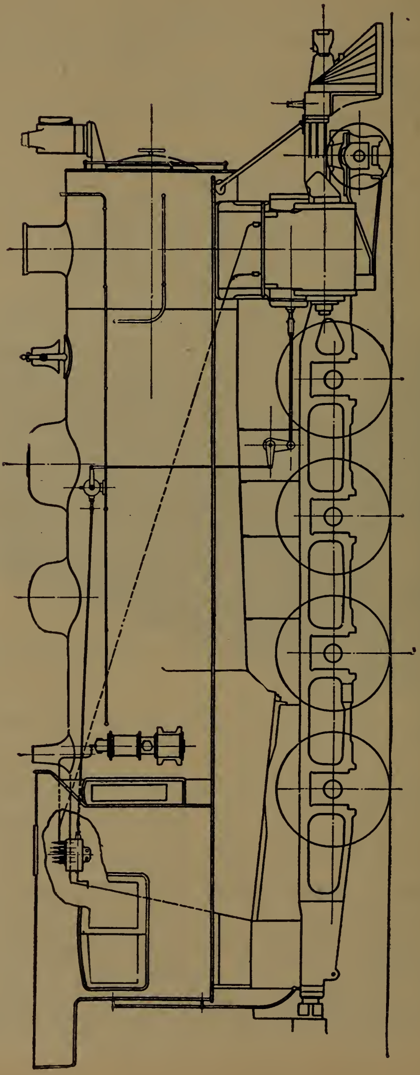


Fig. 26.—McCord Lubricator Attachment

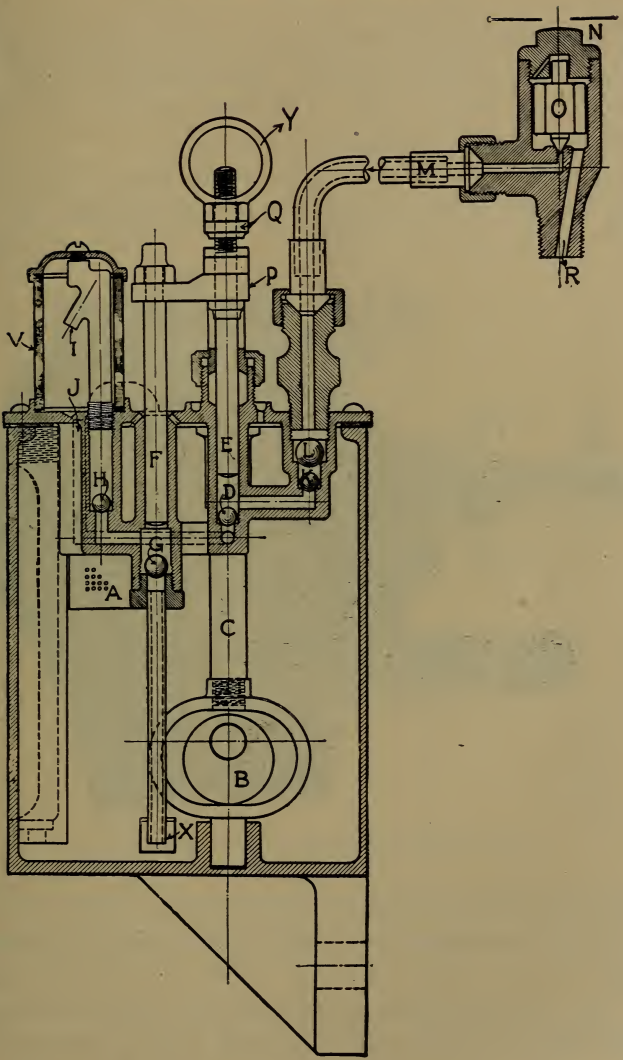


FIG. 27.—McCord Lubricator Section Through One Pump.

downward, the oil is forced past the ball checks *K* and *L*, through the delivery pipe *M*, into the terminal check *N*, where the gravity valve *O* is lifted and the oil forced through delivery passage *R*.

312. The feed is adjusted by lengthening or shortening the stroke of the pump; this is accomplished by the

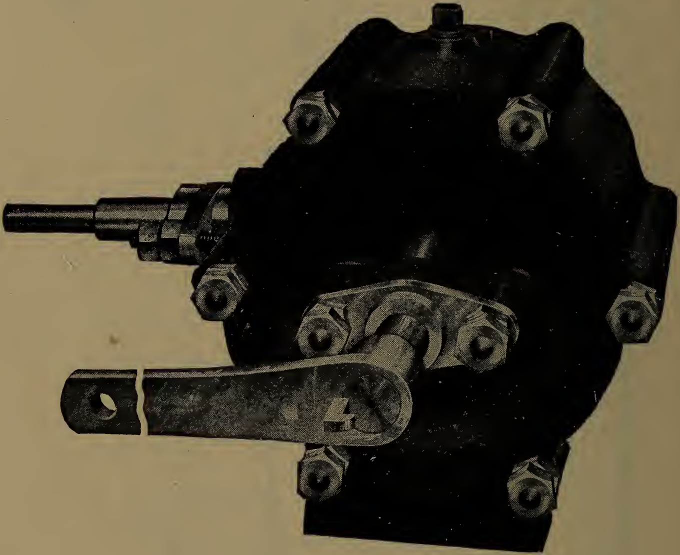


Fig. 28.—Transformer For McCord Lubricator.

adjustment of the nut *Q*, which allows a greater or less amount of sliding of the cross-head *P* on the pump plunger *E*.

313. Any individual pump may be operated by hand at any time, and one or more bearings can thus be given an

extra amount of oil with the machine in full operation, or when idle, and without changing the feed adjustment.

THE TRANSFORMER

314. Referring to Figs. 28 and 29, the names of the different parts of the transformer are as follows: *Y*,

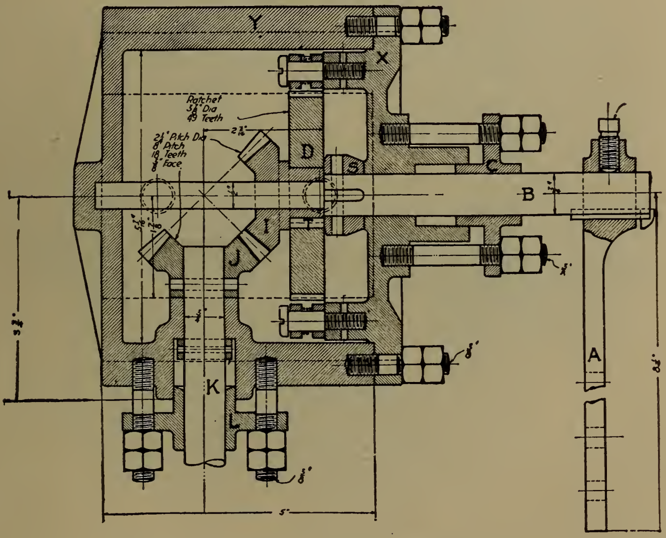


FIG. 29.—Section Through Transformer.

body; *X*, cover plate; *C* and *L*, packing glands; *B*, shaft; *A*, arm; *S*, pawl lever; *E* and *G* are pawls attached to the pawl lever, *S*; *H* and *F* are pawls which are pivoted on the cover plate; *M*, springs; *D*, ratchet wheel; *I* and *J*, miter gear wheels; *K*, shaft which connects to lubricator.

OPERATION OF THE TRANSFORMER

315. When in operation arm *A* receives a reciprocating or to-and-fro motion from the rocker arm or valve stem and imparts it to the shaft *B*. Mounted on the shaft *B* is a pawl lever *S* bearing the two pawls *E* and *G* which

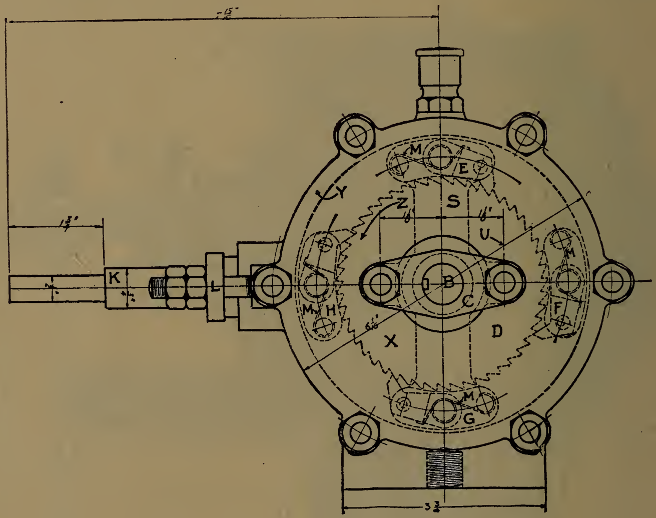


Fig. 30.—Transformer Ratchet.

are held in mesh with the ratchet *D* by the spring *M*. The ratchet *D* is keyed on the miter gear *I* by the key *T* and the whole, as one piece, is mounted loosely on the shaft *B*. Then the miter gear *I* meshes with the miter gear *J*, which is keyed on the shaft *K*, which rotates in the gland *L*. Now as the shaft *B* moves the pawl lever *S* in the direction of the arrow *Z*, the pawls *H* and *F*, which are pivoted on the cover plate *X*, hold the ratchet *D*. Then as the pawl lever *S* moves in the direction of the arrow *U* the pawls

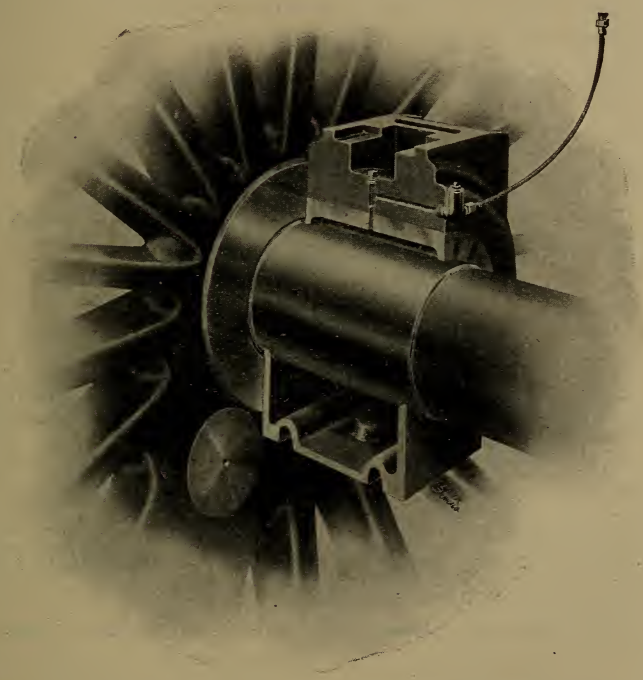


FIG. 31.—How Oil is Applied to the Driving Box with the McCord Force Feed Lubricator.

E and *G* engage the ratchet *D* and move it in the same direction. This in turn rotates the miter gear *I* which in turn rotates the miter gear *J* and the shaft *K*.

316. The transformer case is filled with grease so that the wear is reduced to a minimum.

317. The packing glands *C* and *L* prevent leakage around the shafting.

318. This lubricator requires no pressure in either the oil reservoir or sight feed glasses.

319. When the engine stops lubricator stops.

320. The reservoir can be filled while in full operation.

321. The feed is adjustable from one drop in ten strokes to twenty drops in one stroke.

322. The lubricator will pump against a pressure of more than three thousand pounds.

THE STEAM GAUGE

323. Boiler pressure, as shown by the steam gauge, is the pressure per square inch above atmospheric pressure.

324. In order to find the absolute pressure on the boiler, add 14.7 pounds, the pressure of the atmosphere to the pressure indicated by the gauge; this will give the exact pressure on the boiler reckoned from a vacuum, but as there is 14.7 pounds of atmospheric resistance on the outside of the boiler, there will be no internal force exerted by the steam until it equals the atmospheric resistance on the outside. For this reason the gauge is made to show the pressure above the pressure of the atmosphere instead of from a vacuum.

325. Steam gauges for locomotives arc made with hollow curved tubes as shown in Fig. 32, with one end closed and curved to about the shape of a horse-shoe. A

pipe is connected to this curved tube. At the bottom of the gauge several coils are placed in this pipe and then connected to the boiler somewhere above the water line.

326. The steam in this curved pipe condenses and the curves in it hold the water which is forced by the boiler pressure into the tube in the gauge, filling it with water. The end of this tube is connected to the spindle of the

FIG. 32.—Steam Gauge, Sectional View.

gauge pointer by means of small levers. When the pressure in the curved tube causes it to expand, the tube straightens out, moving the pointer around in proportion to the pressure on the boiler.

327. If a leak should occur in the feed pipe draining the water out of the gauge and admitting dry steam, the gauge will not show the correct pressure on account of the expansion of the tube caused by the excessive heat of the dry steam.

328. The steam gauge and the safety valves are set to

register the same maximum pressure. Should the safety valve not respond when the gauge shows the pressure at which the safety valve is set to raise, the safety valve should be reported and the gauge tested. If the gauge is found to be all right, the safety valve should be set to raise at the proper pressure.

329. When the safety valve refuses to raise at the pressure for which it is set, it becomes a dangerous condition and care must be exercised to keep the pressure down within the limit of safety; if the safety valve is stuck, it can sometimes be loosened by tapping the valve case.

GAUGE COCKS

330. The gauge cocks are a set of three or four valves connected directly with the water in the boiler; they are placed at a convenient place on the boiler head so that the engineer can have easy access to them.

331. The gauge cocks are used for the purpose of showing the exact level of water in the boiler.

332. The water glass is used for the same purpose, but must not be depended upon on account of the liability of sediment gathering in its connections and stopping the free circulation of the water through it.

THE WHISTLE AND BELL

333. The whistle and bell are used for sounding signals and warnings as prescribed by the standard book of rules and as required by law.

334. The engineer is required to sound a warning when approaching public road crossings at grade by two long and two short blasts of the whistle; the whistle must also be sounded at all whistling posts.

335. The engine bell must be rung when an engine is about to move and when approaching every public road crossing at grade and until it is passed. The unnecessary use of either the whistle or bell is prohibited.

THE WATER SUPPLY

336. The supply of water to the boiler should be as near the rate of evaporation as is possible in order to keep the required amount of water in the boiler. Enough water should be carried in the boiler at all times to insure safety, but care should be used to prevent flooding or priming, as water being forced through the cylinders washes all the oil off the walls of the cylinders and is liable to cause damage to the cylinder head.

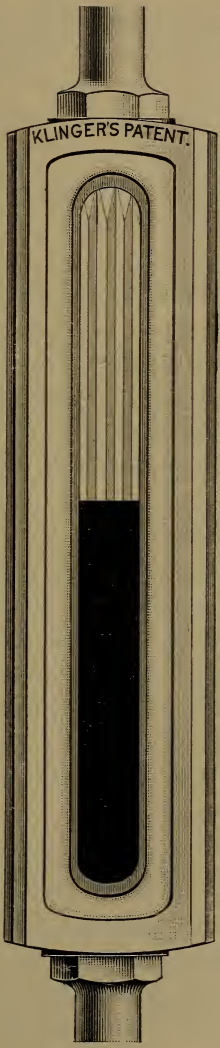


FIG. 33.—Klinger Water Glass.

337. The proper depth of water to be carried in most boilers is about two gauges of water and one of steam.

338. Great care should be exercised in supplying water to the boiler. As much coal can be saved by careful pumping as can be saved by the reverse lever and throttle.

339. When steam is taken from the boiler to operate the injector it takes heat and pressure with it.

340. About two cubic feet of steam are required to each gallon of feed water; the heat which has entered into the feed water has not been lost, but the boiler pressure has been reduced and it is necessary to create more heat to maintain the pressure. Therefore it can be readily seen that the greater the number of gallons of water pumped into the boiler in a given time, the greater the amount of heat necessary to keep up the pressure of steam in the boiler.

341. To supply water to the boiler in the most economical manner, the supply must not exceed the rate of consumption and the supply must be regular.

342. No fireman can maintain a steady steam pressure and save fuel when the boiler is being pumped irregularly. Poor pumping is the cause of a great many engine failures, because the fireman cannot work to any advantage when compelled to have a very hot fire for a short time to keep up the pressure while the boiler is being filled with water and then have to let the fire die down to keep the steam from popping off all the time while a careless engineer allows the water to get lower and lower until compelled to put more water in the boiler to save the crown sheet.

343. The careful, economical engineer will operate the

injector and regulate the water supply just as carefully as he adjusts the reverse lever or throttle.

WATER FOAMING

344. Foaming is a very dangerous condition and when it occurs every precaution must be taken to prevent damage to the crown sheet.

345. This condition is usually first detected by the sound of the exhaust.

346. The exhaust will sound almost the same as if the boiler had been over-pumped and the engines were working water. The water will raise in the glass and the gauge cocks will all show some water. This condition is what causes foaming to be so dangerous.

347. When the above condition occurs, test for foaming before shutting off the injector by easing off on the throttle, trying the gauge cocks at the same time; if the water drops down and the gauge cocks show steam it is pretty certain that the water is foaming. Keep the throttle open to hold the water up, stopping the train with the air if necessary; increase the water supply until certain that the crown sheet will be protected when the throttle is shut off.

THE CAUSE OF FOAMING AND ITS REMEDIES

348. Anything containing alkali, such as alkali water, soap, animal or vegetable oils or grease, will cause foaming; mineral oils as a general thing do not cause foaming and may be used to advantage in preventing foaming.

349. Carbon oil has a tendency when injected into the boiler with the feed water to calm the water and cause it to settle to its proper level; the oil also has a tendency to loose the boiler scale and sediment which collects on the sheets and flues and make it easier to remove.

350. Blue vitriol placed in the supply hose back of the strainer will help to modify the effects of the grease or oils in the water.

351. When taking water allow the tank to overflow; this will remove the oils and grease which gather on the surface of the feed water.

352. If the boiler has a surface cock it should be opened to skim the impurities from the surface of the water.

353. If the blow-off cock is opened, great care should be exercised to prevent the water getting too low; the injectors should be put to work to maintain the water level while the blow-off cock is open.

354. When it is desired to shut off the blow-off cock and scale prevents its being closed, open the valve a little more and then shut quickly. This will usually remove the scale and no trouble will be experienced in closing the valve.

RUNNING WITH BAD WATER

355. This condition calls for skillful handling by the engineer to protect his engine and still be able to move his train. To do this the water level should not be any higher than safety requires; the reverse lever should be set several notches lower than usual and the throttle should be run as near closed as the circumstances will permit. By

doing this, the water is not disturbed so much by the current of steam entering the throttle and the water will not be raised as much as if the throttle was wide open and the reverse lever near the center. Always use the cylinder cocks when the water is foaming to draw the water out of the cylinders and prevent damage to the cylinder heads. Do not fail to report bad or foaming water at the end of each trip; it may prevent an engine failure on the next trip.

PRIMING

356. Priming is caused ordinarily by over-pumping and may be detected by the sound of the exhaust which is not so sharp as usual, having a muffled tone. This condition is so similar to that of foaming that care should be exercised until a test has been made for foaming. If the test shows priming, open the cylinder cocks, shut off the water supply, and ease off the throttle; run slow until the water level has been lowered.

357. Priming is very detrimental to the engine, washing all the oil from the valves and cylinders, causing a great deal of friction, using more fuel and more oil to get the valves and cylinders properly lubricated again. Priming is liable to damage the cylinder heads because water cannot be compressed to any great extent and if water is in the cylinder the piston will force it against the cylinder head with such force as to damage the head.

STEAM

WHAT IT IS AND HOW GENERATED

358. Steam is an elastic substance generated from water by the continual application of heat.

359. Steam is generated at a temperature above 212° F., the exact temperature depending upon the pressure to which it is subject.

360. With a boiler pressure of 180 pounds per square inch, the temperature of the water and steam in the boiler will be 379° F.

361. The expansive properties of steam are such that at 180 pounds pressure it is capable of expanding from eight to twenty-six times its original volume, the amount of expansion depending upon the pressure to which it is subject when exhausted.

362. The expansive property of steam is due to the heat which it has absorbed. This is proven by the fact that water and steam being forced from separate nozzles at 180 pounds pressure, the heat contained in the steam would cause it to expand, discharging from the nozzle at a velocity of about 3,600 feet per second, while the water containing no heat is not capable of expansion and reaches a velocity of only 164 feet per second, so that it can be readily seen that the steam is capable of doing much more work than the water from which it is generated.

363. This also proves that the heat generated in the fire box and absorbed by the water is the real power that

does the work and that the water is only a medium for its transportation.

364. Steam is either saturated or superheated.

365. Saturated steam is the steam which is generated from the water in the boiler and contains just sufficient heat to keep it in the state of steam.

366. The temperature of saturated steam depends upon the pressure under which it is generated and any loss of heat will cause some of the steam to revert to water.

SUPERHEATED STEAM

367. Saturated steam may be superheated by separating it from the water from which it is generated and adding more heat to it.

368. In order to superheat steam it must be separated from the water in the boiler because any increase of heat will produce more saturated steam instead of superheating the steam already generated.

369. The term saturated steam is often misunderstood, because all steam is either saturated or superheated.

370. The steam which rises to the dome and passes through the throttle valve to operate the engines is called dry saturated steam.

371. Dry steam is steam which has not more than three per cent of moisture. Steam having over three per cent of moisture is called wet steam.

372. Superheated steam contains such an excess of heat that no moisture is apparent and may lose some heat without causing condensation, but just as soon as it loses

all of its excess heat condensation begins to take place and the steam becomes saturated.

HOW STEAM PASSES THROUGH THE ENGINE AND OPERATES IT

373. Steam, being generated from the water in the boiler by the heat from the fire box, rises to the dome where it passes through the throttle valve into the dry pipe, through the dry pipe to the steam pipes in the front end, then through supply passages in the cylinder saddle to the steam chest, being admitted to the cylinder by a valve through a port in its seat. The steam entering the cylinder pushes the piston to the opposite end of its stroke; the valve now moves over so that a cavity in its face covers the supply port and the exhaust port in the valve seat.

The steam, after doing its work in the cylinder, escapes through the same port through which it was admitted to the cylinder, then through the cavity in the valve and exhaust port in its seat to the monument stack and the open air.

While the steam is passing from the end of the monument in the smoke box to the stack, it creates a vacuum in the smoke box. Air rushing in through the fire box and flues to supply this vacuum acts as a blower on the fire.

NAMES OF PRINCIPAL PARTS OF THE LOCOMOTIVE

374. It is necessary for the student to be thoroughly familiar with the names of the different parts of the locomotive so that he may be able to know just what he is talking about on examinations and when making out his work reports.

375. The Boiler.—Outer fire box, inner fire box, flues, smoke box, barrel, throat sheet, mud ring, water leg, boiler head, flue sheet, side sheets, crown sheet, door sheet, fire door, hook and latch, fire door chain, fire door damper, gauge cocks, hand hole plates, blow-off cock, washout plug, friction plates, stay bolts, crown bolts, radial stays, dry pipe, nigger head or steam pipe tee, draft apron, steam pipes, netting, monument, stack, spark hopper, smoke box door, number plate, head light, head light brackets, signal lamps, signal lamp brackets, signal flag brackets, hand rail, sand box, sand pipes, sand lever, sand blower, dome, safety valve, whistle, bell, bell ringer, spider, globe valve, injectors, injector steam pipe, injector feed pipe, branch pipe, boiler check valve, squirt pipes and hose, steam gauge, throttle valve, throttle stem, throttle lever, throttle packing, throttle packing gland, surface cock, blower valve, blower pipe, air pump steam valve, cab lamp, cab lamp bracket, lubricator, lubricator steam valve and pipe, tallow pipes, grate bars, grate bar rack, grate bar shaker, ash pan, ash pan dampers, damper rods, boiler lining, boiler jacket, cab, running board, etc.

376. The Engine.—Main frames, pedestal jaws, pedestal braces, cylinders, cylinder saddle, steam chest, valve, valve yoke, balance strips and springs, friction plate, valve seat, steam ports, exhaust ports, back cylinder head, front cylinder head, piston rod, piston head, cylinder packing rings, follower head, piston packing, piston packing gland, piston packing spring, guide bars, cross-head, cross-head shoes, cross-head gibbs, cross-head wrist pin, guide yoke, main rod, main rod brass, main rod key and liner, main pin, main wheel, main driving box, main axle, wedges, shoes, counterbalance back driving wheel, main driving wheel, intermediate driving wheel, front driving wheel, engine truck, engine truck center casting, bull nose, pilot, pilot brace, bumper beam, marker brackets, back driving box, main driving box, intermediate driving box, front driving box, truck boxes, oil cellars, driving springs, truck springs, trailer truck, equalizers, spring hangers, side rods, side rod knuckle joint pin, valve stem and yoke, valve stem packing and packing gland, valve stem key, rocker shaft, transmission rod, transmission rod hangers, link, link block, link hanger, link saddle, saddle pin, forward motion eccentric rod, back motion eccentric rod, eccentric straps, eccentric blocks, tumbling shaft reach rod, reverse lever, quadrant, cylinder cocks, cylinder cock rigging, tail casting, friction plate, chafing block, chafing block spring, brake shoes and rigging, tender, coal pit, water cistern, man-hole, man-hole lid, tank valve, tender trucks, draw bar, tool box, safety bars, draft timbers, etc.

Part Three

LOCOMOTIVE BREAKDOWNS AND THEIR REMEDIES

377. The first thing to do when an accident or breakdown occurs is to protect against further trouble by flagging all tracks until the extent of the injury or trouble has been ascertained, after which the flag can be recalled if not needed.

378. The next most important move is to clear the main track as quickly as possible to avoid delay to other trains.

379. If the engine cannot be moved and the accident is a serious one, which will occasion considerable delay, notify the proper authorities as soon as possible so that means may be taken to clear the track.

Nearly all railroads have steam derricks and wreck trains ready at all times for immediate use and would rather have the wreck train called to clear the wreck than to have the system blocked even for a short time while the train crew was trying to clear the track without sufficient help or tools to do the work. However, conditions vary on different systems and engineers must conform to the rules in force on their respective roads.

FRONT CYLINDER HEAD

380. If a front cylinder head is knocked out and the piston not damaged, clamp the valve on center, disconnect the valve stem and proceed on one side, with the light engine. It is not considered practical to try to haul cars with one of the large engines on one side, because of the trouble of getting it off center in case it should stop on the dead point. When the cylinder head is broken out the cylinder can easily be oiled through the broken part, but if the cylinder cannot be oiled through the broken head keep the lubricator working and move the valve to one side, occasionally uncovering the port to the cylinder. The oil which has been gathering in the steam chest will pass through the port and lubricate the cylinder; then cover the ports again, clamping the valve stem, and proceed under ordinary conditions. An engine will run 28 to 30 miles without oiling without danger of cutting. Keep the cylinder cocks open on the damaged side.

BACK CYLINDER HEAD

381. If a back cylinder head is badly damaged, place the valve on center, disconnect and clamp the valve stem, take down the main rod, push the cross head to the rear end of the guides and block it there. Guide blocks are usually furnished for this purpose, but in case they should not be, a piece of boaid fit in between the cross-head and the guide block will answer the same purpose; the board can be lashed to the guide with a piece of bell cord to keep

it from losing out. In some cases with certain classes of engines when the main rod is taken down, it is necessary to place small strips of wood around the main pin between the collar and the side rod to keep it from slipping sideways far enough to do damage to the rods; then proceed on one side, keeping the cylinder cocks open on the disabled side.

CROSS-HEAD

382. If the cross-head is broken so badly that it will not slide safely in the guides, place the valve on center, disconnect and clamp the valve stem; take down the main rod and block the cross-head at the back end of the guides; open the cylinder cocks on the disabled side.

In any case, where the main rod is taken down, always block the cross-head so that it will not slide back and forth in the guides as it might knock out a cylinder head or damage the guides. Blocking the piston at one end of the cylinder with steam, by placing the valve to one side of the center so that steam will enter the cylinder on one side of the piston only, is a bad practice and should not be followed because of the liability of the piston moving when the throttle is shut off and the engine drifting, and when steam is used again the piston would be forced back with such force as to result in serious damage.

MAIN ROD

383. If a main rod should be bent or broken, remove the rod, clamp the valve on center, disconnect the valve stem, and block the cross-head.

SIDE RODS

384. If a forward or back connection is broken, take down the broken part, also the corresponding part on the other side.

385. If a main connection is broken, take down all side rods on both sides, in all cases when it is necessary to remove a side rod. The corresponding rod on the other side must be taken down to prevent damage to the rods.

MAIN PIN

386. If a main pin is broken off at the wheel, remove all side rods on both sides and the main rod on the damaged side; disconnect the valve stem and clamp the valve on center and block the cross-head on the damaged side. Reduce the steam pressure, place the reverse lever at full stroke, use a light throttle and proceed, moving the engine with one main rod. When this condition occurs with a large engine with heavy rods, and it is important to clear the main track, send for assistance immediately and prepare the engine to be towed in.

FRONT, BACK, OR INTERMEDIATE PINS

387. If a front, back, or intermediate pin is broken, proceed the same as for a broken front, back, or main side rod connection.

MAIN AXLE

388. If a main axle is bent or broken between the frames, take down the main and all side rods on both sides, block the cross-heads, take down both main box oil-cellars and block between the pedestal braces and the axle, raising the wheels off the rail. To do this place a block between the top of the intermediate driving box and the frame, then place wedges on the rail in front of the intermediate wheels; when assistance arrives have the engine moved, running the intermediate wheels up on the wedges. This will lift the main wheels off the rail because of the blocks placed between the pedestal brace and the axle; now place blocks of sufficient length under the main wheels so that they will not drop off the blocking when the engine is moved to let the intermediate drivers down off the wedges. Now place more blocking between the pedestal brace and the main axle, move the engine so that the blocking under the main wheels can be removed, and the engine is ready to be towed in with the main wheels suspended.

389. If the main axle is broken off just outside the box the wheel would, of course, be removed in this case, to level up the axle. The end of the axle and driving box may be raised by means of a long lever with a chain around the axle and over the short end of the lever, using the engine frame as a fulcrum; blocking can then be placed under the axle.

FRONT AXLE

390. If the axle is broken between the frames it will be necessary to disconnect the side rod connections on both sides. Block between the top of the intermediate driving boxes and the frame, then remove the oil cellars and block between the pedestal braces and the axles of the disabled wheels. With engines having long truck equalizers block between the frame and the ends of the equalizer cross suspension bar.

391. If the wheel is broken off outside of the driving box, remove the wheel and the front side rod connections on both sides. Level up the axle and driving box on the broken side by blocking between the pedestal brace and axle. Place a block between the top of the intermediate box and the frame on the broken side and a wedge between the frame and spring saddle of the broken axle. The engine is now ready to be moved.

INTERMEDIATE AXLE

392. If an intermediate axle is broken between the frames it will be necessary to suspend the wheels. Take down all side rods and block between the pedestal brace and axle. Place a block between the top of the front driving box and the frame, then run the front driver up on wedges. Now block between the top of the main driving box and frame, then run front drivers off the wedges, reduce the steam pressure, and the engine is ready to be moved.

REAR AXLE

393. If a rear axle is broken or damaged so that it will not turn or carry its share of the weight, remove the back side rod connections on both sides. Remove the oil cellars from the back driving boxes and block between the pedestal brace and the axle; then block between the top of the main driving box and the frame; now place a cross tie across the space from the engine to the tender deck; place a heavy chain around the tail casting and the cross tie; this will transfer some of the weight of the engine to the tender. If the main drivers have blind tires and the engine is of the large heavy class, the best and safest plan is to use an emergency truck to support the weight and guide the rear of the engine to keep it on the track. If an emergency truck cannot be secured saw off two pieces of cross tie and wedge between the tender and engine, one on each side; this will make the tender and engine rigid so that the tender trucks will guide the rear of the engine. Run very slowly and carefully to avoid derailing the engine.

394. If a rear wheel is broken off outside of the driving box, disconnect the back connections of the side rods and block the same as for an axle broken between the frames. Leave the opposite wheel on the rail; place a heavy chain around the frame on the disabled side and fasten to the tender on the opposite side. This will hold the flange of the good wheel against the rail. Always remember to cut out the driver brake when a driving wheel or axle is disabled.

BROKEN TIRE

395. When a tire breaks, suspend the wheel the same as for a broken axle; the wheel can be raised to block up for a broken tire by running the wheel up on wedges and then blocking between the pedestal, brace, and the axle, then block between the spring saddle and the frame; block between the driving box and frame of the driver next to the disabled one.

It is not considered safe to leave the side rods up that are connected to a suspended wheel.

TO REMOVE FRONT SIDE ROD CONNECTION

396. To disconnect and remove the front side rod of an *H*-6*a* or *H*-6*b* engine, disconnect at the knuckle joint. Now move the engine until the pin is on the top quarter; now dig the dirt from between two ties, place the end of the disconnected rod in the hole, and move the engine back; this will turn the rod upside down. Now remove the oil cellar from the front driving box and run the intermediate driver up on a wedge, moving the pin to the bottom quarter at the same time. The rod can now be slipped off the pin under the guides. The reason for turning the rod upside down is to get the oil- or grease-cup on the under side so that it will not interfere with the guide. The intermediate driver is run up on a wedge so that the front driver will drop down as low as possible to permit the removal of the rod under the guides.

397. Another way is to disconnect the front end of the main rod, pushing the cross-head forward. Move the wheel so that the pin will be on the back center, when the rod can be removed and the main rod connected up again.

TO REMOVE THE VALVE STEM PIN FROM THE ROCKER ARM

398. As many engineers know, this is sometimes a very hard and aggravating task. If a pinch or claw bar can be secured, place a block so that the end of the pin can be used as a fulcrum for the bar. Then strike the rocker arm on the same side as the head and just under the pin. This method has proved successful when all other means at hand have failed.

BROKEN VALVE YOKE

399. Should a valve yoke break, disconnect and clamp the valve stem the same as if the yoke was not broken; now remove the relief valve or plug from the front of the steam chest and with a bar shove the valve back against the part which has been clamped; now cut a piece of wood of the proper length and drive in against the valve. Cut the piece of wood so that the relief valve or plug may be screwed into place and solid against the blocking; this will place the valve central on its seat covering the ports. Disconnect the cylinder cock rigging, blocking the cylinder cocks open on the disabled side. Proceed with one side working.

MAIN STEAM VALVE, STEAM PIPE, OR STEAM CHEST

400. If a main steam valve, steam pipe, or steam chest is badly damaged or broken, it will be necessary to be towed to the shop. Keep enough steam on the engine to operate the lubricator and it will not be necessary to disconnect unless the broken part interferes with the movement of the valves.

BROKEN ECCENTRIC STRAP OR ROD

401. In case one eccentric strap or rod is broken, both straps and rods on the disabled side must be taken down and the top of the link tied to the tumbling shaft or some other support. Clamp the valve on center on the damaged side and proceed.

BROKEN SPRING, SPRING HANGER, OR EQUALIZER

402. If a spring, spring hanger, or equalizer is broken, remove all loose parts, block between the driving box and the frame in order to level up the engine. With some classes of the large engines now in use the equalizers have been placed so near the frames that when a spring or hanger breaks the equalizer will come in contact with the frame in such a way as to keep the frame from riding the driving box. In this case remove the loose parts and proceed.

403. If a long truck equalizer breaks, run the intermediate drivers up on wedges and block between the front driving boxes and the frame; now run the intermediate drivers off the wedges, remove the broken parts of the equalizer, and proceed.

BROKEN REVERSE LEVER, REACH ROD, LINK HANGER, OR TUMBLING SHAFT

404. Should any of these parts be broken with the Stephenson valve gear, place a block in the link on top of the link block. The block should be long enough to give the desired cut off; then place another block below the link block to prevent the block slipping in the link. To reverse the engine change the position of the block in the link.

BREAKDOWNS OF THE WALSCHAERT VALVE GEAR

405. The Walschaert valve gear, on account of its simple construction, does not often break down. The valves used with this gear are just the same as those used with other styles of valve gears.

406. In explaining the breakdowns of the Walschaert valve gear it is well to remember that the rules for breakdowns are just the same for engines equipped with the Walschaert valve gear as for the Stephenson gear, up to the point where it is necessary to disconnect the valve stem when the valve is clamped central on its seat.

407. When the valve gear itself is not injured but for some other cause, the valve must be clamped central on its seat. Place the valve stem cross-head central in its guide; the valve will then be central on its seat with both ports covered; clamp the valve stem by cocking the packing gland or by placing a thin strip of wood or iron between the valve stem guide and valve stem cross-head and clamping it there. Now remove the bolt from the front end connection of the radius rod 7, Fig. 9, to the combination lever 9.

Disconnect the lift shaft connection 14 to the radius rod at *d*, dropping the radius rod and link block to the bottom of the link, 5, now remove the eccentric rod 6, then move the front end of the combination lever 7 up out of the way of any movable part, now move the engine slowly and if the cross-head pin does not strike the combination lever 9, it will not be necessary to disconnect union link 10, but if the cross-head pin interferes with the combination lever 9, the union link 10 must be taken down and the lower end of the combination lever 9 moved forward to clear the cross-head and then wired to the back cylinder cock.

BROKEN ECCENTRIC ROD

408. If eccentric rod 6 breaks, remove the broken parts, clamp the valve on center, disconnect the lift shaft 14 from the back end of the combination lever at *d*, drop the link block and combination lever to the bottom of the link, disconnect the union link 10, and wire the lower end of the combination lever 9 to the cylinder cock as there

will be no motion imparted to the link or upper end of the combination lever. It will not be necessary to disconnect the front end of the radius rod 7.

BROKEN ECCENTRIC CRANK OR LINK EXTENSION

409. For a broken eccentric crank or link extension, proceed the same as for a broken eccentric rod.

BROKEN LIFT SHAFT OR RADIUS ROD HANGER

410. Disconnect the broken parts and set the reverse lever in the position at which it will give the desired cut-off, then measure the position of the block in the opposite link, then cut two pieces of wood and fit in the link above and below the link block so that it will be in just the same position as the opposite link block. Do not have the blocks too long or they will bind on the link block; a quarter of an inch clearance will not be too much. When necessary to reverse the engine change the position of the blocks in the link.

BROKEN RADIUS ROD

411. If a radius rod is broken in front of the link remove the broken parts, clamp the valve on center, disconnect the radius rod hanger at *d*, and if the part in front of the link block is long enough wire it up out of the way; if not long enough, take it down, leaving the eccentric rod

up. If the combination lever interferes with the cross-head pin disconnect the union link and wire the combination lever to the cylinder cock.

BROKEN CROSS-HEAD ARM

412. If a cross-head arm, 11, should break remove the union link, clamp the valve on center, then wire the combination lever so that it will not interfere with the cross-head, disconnect the lifting link from the rear end of the combination lever, dropping the link block to the bottom of the link, disconnect the eccentric rod and proceed on one side. For a broken union link, 10, proceed in the same manner as for a broken cross-head arm.

BROKEN COMBINATION LEVER

413. Remove the union link; if the lever is broken near the lower end, wire the remaining part forward, out of the way of movable parts, and proceed as for a broken cross-head or union link.

BROKEN CROSS-HEAD

414. When necessary to remove the main rod, as for a broken cross-head, clamp the valve on center, remove the eccentric rod, 6, and disconnect the back end of the combination lever 7, block the cross-head and proceed, working one engine.

Some engineers prefer to block the radius rod and link block in the center of the link instead of taking down the eccentric rod. In cases where it is necessary to disconnect the radius rod-hangers this method is practical, but where blocks are not furnished for the purpose it usually takes more time to find wood and prepare the blocks than it would to take down the eccentric rod. For this reason it is considered preferable to take down the eccentric rod, except in cases where the engine can be used by blocking the link block.

In disconnecting the Walschaert valve gear a great deal depends upon the manner and extent of the injury. This gear, being on the outside of the engine frames, is more liable to damage by coming in contact with objects which do not clear the engine than other gears and for this reason is often twisted into such shapes as to call for the greatest knowledge and ability of the engineer in disconnecting. In such cases the engineer should follow his best judgment in the matter as he will be held responsible for any further damage which may be caused by his lack of knowledge or ability to take care of conditions as he finds them, even though no established rule will apply.

TESTING FOR BLOWS

To test for blows with the inside admission piston valve proceed in the following manner:

415. Place the main pin just a little in front of the bottom quarter line and the reverse lever in the center of the quadrant; the valve is now central on its seat. Set

the driver brake and open the cylinder cocks; now give the engine steam, and test for valve-blows first.

416. If steam appears at either cylinder cock the inside packing ring is blowing on that side; if steam also blows through to the stack it indicates that the end or exhaust ring is blowing; when a continuous blow occurs and no steam appears at the cylinder cocks while the valve is central on its seat, it is a pretty sure guess that the by-pass valve is blowing.

TO TEST THE CYLINDER PACKING

417. With the engine in the same position as that described for testing the valve, place the reverse lever in the full forward position, moving the valve forward, uncovering the front steam port admitting steam to the front end of the cylinder; if steam blows through to the back end of the cylinder, steam will appear at the back cylinder cock and the exhaust. To prove this test place the reverse lever in the full back position and give the engine steam; the valve is now admitting steam to the rear end of the cylinder; if steam blows through to the front end of the cylinder, blowing at the front cylinder cock and the stack, it confirms the first test.

418. To test for blows with an outside admission piston or balanced slide valve, proceed the same as described for an inside admission valve. The only difference being that the position of the valve when moved from its central position on its seat, will be just the opposite of the inside admission valve, as the full forward position of the inside

admission valve will admit steam to the front steam port and exhaust it from the back port, while the outside admission valve would be in the full back position to admit the steam to the front port and exhaust it from the rear port.

419. There are several kinds of blows for which there is really no practical road test, as they are so similar in sound and appear at the same time in the test. When these blows occur, test for all the blows which can be located with some certainty and then report the steam valve and chest examined for the others. Some of these blows for which there is no absolutely sure test are a sand hole from the steam to the exhaust passage, a cracked bridge, balance strips blowing, or when both ends of the valve and the cylinder packing blow at the same time. This condition calls for an examination of the parts.

420. A cylinder packing blow has a muffled tone or roar, while a valve blow is sharp and distinct. A cylinder packing blow will be intermittent, commencing just after the main pin has passed the center and continuing with increased volume until the pin has reached a point near the top or bottom quarter. In the forward motion the blow will appear while the pin is between the forward center and the bottom quarter and between the back center and the top quarter.

If in the back motion, the blow will occur while the pin is between the forward center and the top quarter and between the back center and the bottom quarter.

421. A valve blow will be more continuous, with a little variation of sound during full exhaust port opening.

POUNDS—HOW LOCATED

422. Inspect the engine carefully for loose or broken parts; then place the engine on the top quarter, set the brakes and give the engine a little steam, have the fireman throw the reverse lever ahead and then back a few times. While the engine is being thumped, as it is commonly called, the engineer should note the lost motion of each connection of the rods, brasses, cross-head, etc. Now release the brakes and repeat the thumping process, noting the lost motion of the driving boxes, condition of the wedges, etc. By this test the engineer can readily discover all pounds and either remedy them or make an intelligent report.

DRIVING BOX ADJUSTMENT

423. In order to keep the centers of the different driving axles in tram or an equal distance apart (so that they will work in perfect harmony with each other), the driving boxes which are fitted to each journal are placed between the jaws of the frame or pedestals. Shoes are placed between the pedestal jaws and the driving box to keep the jaws from wearing. An adjustable wedge is placed between the back shoe and pedestal jaw of each box. By means of this wedge the lost motion of the driving boxes can be taken up and the wheel and pin centers kept in tram. The adjustment of wedges is a very important matter, as a wedge out of place causes a very severe pound and strain on the frame, side rods, and pins. The shoes should be

kept well oiled so that the driving boxes will move up and down with as little friction as possible when the wheels strike uneven places in the track.

DRIVING BOX WEDGES

424. Driving box wedges should be adjusted by placing the engine on the top or bottom quarter; thump the boxes away from the back shoes and hard against the front shoes; now set up the wedges as far as they will go, then draw them down far enough to allow the boxes to move in the shoes without sticking. If the wedges are set up too tight the boxes will stick in the shoes; this will cause a very rough riding engine and is liable to damage the frames. With a driving box stuck in the shoes the engine will ride just the same as if it had no spring support for that box.

THE THROTTLE VALVE COCKED OR DISCONNECTED

425. If the throttle valve becomes cocked, or will not shut off tightly, apply brakes and open throttle wide, then close it quickly; this will often remove scale which has lodged in the valve.

426. If the throttle valve becomes disconnected while running and it does not seat, set the brakes at once, then place the reverse lever in the center of the quadrant and reduce steam pressure as quickly as possible.

427. After the steam pressure has been reduced to such an extent that the reverse lever can be safely handled,

open the cylinder cocks, set the brakes and move the reverse lever quickly ahead, then back on center. This will cause a sudden movement of steam through the throttle valve and will sometimes cause it to close. If this means

Fig. 34.—Throttle Valve Case.

is not effective place the train on the nearest siding and notify the proper authorities.

428. The engine may be run in to the terminal, under its own steam, but it is not good policy to try to handle a

train, especially with the large class of engines, any farther than to get it off the main track.

429. One of the quickest and most effective ways of reducing steam pressure is to blow steam back through the overflow pipe of one injector, supplying water to the boiler with the other one; open the fire door and open the blower valve a little to cool the furnace. Use the reverse lever and

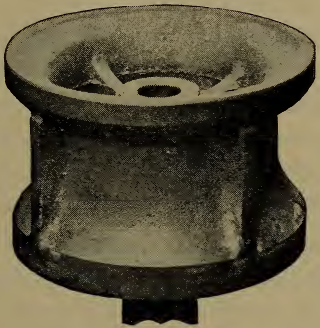


FIG. 35.—Throttle Valve.

brakes to control the movement of the engine. Great care must be used not to slide the wheels and flatten the tires.

430. If the throttle is closed when it becomes disconnected, send for assistance at once and prepare to be towed in. Keep enough steam on the boiler to operate the lubricator and it will not be necessary to disconnect the engine.

SAND AND ITS USE

431. Sand is used for the purpose of increasing the friction between the wheel and the rail; this increased

friction will increase the adhesion and prevent the slipping of the drivers; it also increases the friction of the brake shoes against the wheels, reducing the speed of the train much more quickly than if no sand was used.

432. There are several different styles of devices for applying sand to the rails. There is the old hand lever device, which is still retained in connection with the new pneumatic sanders, so that when they get out of order the hand lever can be used.

433. Great care should be exercised in using sand. While sand is at times a necessity, a little is better than none at all, but too much is almost as bad as none; because the sand when used in too large quantities retards the rolling of the wheels and increases the resistance of the train to such an extent that if the engine is loaded very near to its total tractive power, it will stall the engine.

434. The hand lever sander is very hard to regulate and for this reason other devices are used which distribute the sand more uniformly and can be regulated to feed light or heavy as may be desired.

435. The use of sand on the movable parts of an interlocking plant is positively prohibited.

436. When an engine slips, do not use sand until the engine has stopped slipping, ease off on the throttle until the slipping stops, then drop sand and open the throttle gradually; the reason for not dropping sand while the engine is slipping is that if the wheels were stopped suddenly it might result in damage to the rods or pins and might slip the tires on the wheels. To avoid trouble take the safe course and run no risk.

THE MALLET ARTICULATING COMPOUND LOCOMOTIVE *

GENERAL CONSTRUCTION

437. In general construction the Mallet (Mallay) type of locomotive, named after its inventor, consists of two engines placed under one boiler.

438. The driving wheels are divided into two groups and each group is rotated by a separate pair of cylinders, arranged on the compound system.

439. The high-pressure cylinders drive the rear group of wheels and the low-pressure cylinders the forward group.

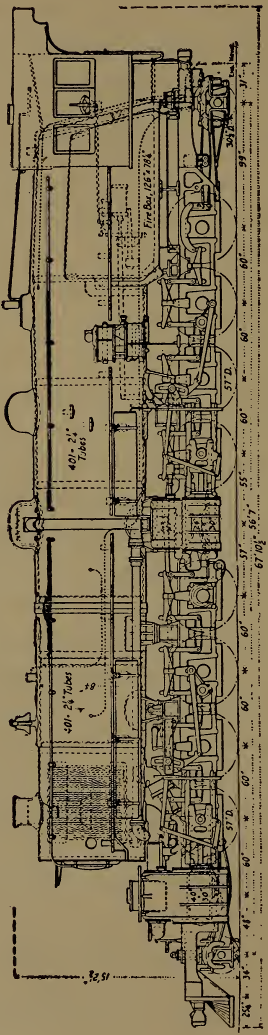
440. With this arrangement the wheel base is necessarily long; therefore to provide the required flexibility, the front frames are hinged to the rear frames at a point on the center line of the engine, between the high-pressure cylinders.

441. The boiler is held in rigid alignment with the rear frames and the forward end or overhang is supported on the front frames by sliding bearings. With these engines two such bearings are provided.

442. The forward bearing is fitted with controlling springs, which are thrown into compression when the front group of wheels are displaced on a curve; these springs thus tend to hold the front group of wheels in alignment with the boiler.

443. In this type of locomotive the receiver pipe con-

* Descriptive extract from B. of L. E. Journal, by permission of the Editor. Mr. C. H. Salmons.



CLASS 20-$\frac{46}{78}$-$\frac{1}{3}$-E E-3. DOUBLE CONSOLIDATED MALLET TYPE LOCOMOTIVES BUILT FOR UNION PACIFIC R. R. CO. ROAD NOS. 2000 SERIES.

FIG. 36.—Mallet Locomotive, Double Consolidated.

necting the high- and low-pressure cylinder and the exhaust pipe connecting the low-pressure cylinders with the smoke box, are necessarily provided with flexible joints. These joints are very simple in construction and as they are subject to very moderate steam pressure, they are easily kept tight.

444. The boiler is straight-topped, 84 inches in diameter. The fire tubes are 21 feet long, they terminate in a combustion chamber 54 inches long, in front of which is a feed water heater 63 inches in length.

The tubes in the feed water are set in alignment with the fire tubes and are equal to them in number and diameter.

445. Water is supplied to the heater by two Nathan simplex type R injectors. The heater is thus kept constantly filled. The feed water leaves it through an outlet on the top center line and enters the boiler through two checks, placed right and left immediately back of the front tube sheet.

446. The feed water is provided with one consolidated safety valve set to open at a pressure of 220 pounds.

447. The combustion chamber is entirely unobstructed and is provided with a manhole, so that it may be easily entered. The tube ends are thus readily accessible.

448. The combustion chamber is surrounded by a separable joint. This is effected by riveting a ring to each boiler section and uniting the rings by 42 bolts $1\frac{1}{4}$ inches in diameter.

449. The rings are butted with a V-shaped fit. The

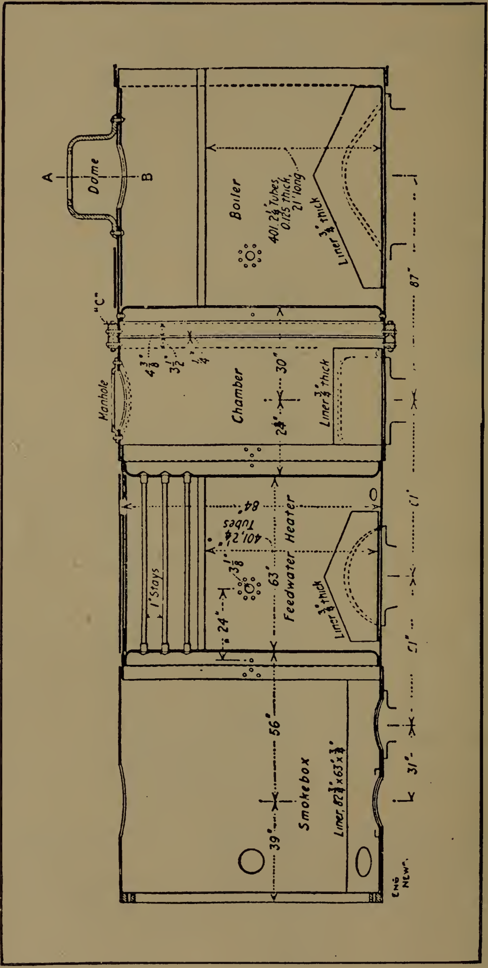


FIG. 37.—Boiler Extension and Feed Water Heater, Mallet Locomotive.

entire design is so arranged that the locomotive can be readily separated into two sections.

The dome is made of cast steel and is placed immediately above the high-pressure cylinders.

450. The throttle valve is of the usual balanced type and communicates directly with two external pipes, which convey the steam to the high-pressure steam chests.

451. The exhaust from the high-pressure cylinders passes into two horizontal pipes which lead forward to the smoke box, where is installed a reheater of the Baldwin type. This device is arranged in two sections one for each cylinder. Each section consists of two drums, one placed in the top and the other in the bottom of the smoke box and these drums are connected by rows of curved tubes, among which the hot gases circulate, before they enter the stack.

452. The steam flows through successive groups of these tubes and is thus dried and reheated before entering the low-pressure cylinders.

In this way condensation in these cylinders which are of large size and much exposed to the cooling effects of the atmosphere, is avoided.

453. The steam enters the reheater at the front end of the device and passes successively through six groups of tubes. It then enters a T connection, from which it is conveyed to the low-pressure cylinder, through a single pipe having a ball joint at each end and a slip joint in the middle; the slip joint is fitted with a gland and made tight with metallic packing.

454. Each low-pressure cylinder is cast separately and

is bolted and keyed to a large steel box casting, which extends from frame to frame.

This casting is suitably cored out to convey the steam from the receiver pipe to a pair of short elbow pipes, making final connection with the low-pressure steam chest. The exhaust then passes out through the front end of each cylinder casting into a T connection and then passes to the exhaust nozzle through a second flexible pipe.

455. The slip joint in this pipe is made tight by means of snap rings and leakage grooves.

At the smoke box end, the ball joint is fitted with a coiled spring which holds the pipe against its seat.

456. Both the high- and low-pressure cylinders are fitted with 15-inch piston valves.

457. The high-pressure cylinders are lubricated by one Nathan No. 9 triple bull's eye sight feed lubricator, which is placed in the cab.

458. While the low-pressure cylinders are lubricated by two Hart force feed oil pumps; these are driven from the valve motion of the front engine and the necessity of using flexible oil pipes for the front cylinders is thus avoided.

459. Both the high- and low-pressure valves are operated by the Walschaert valve gear and is set at 5-16 lead for all the cylinders.

460. Reversing is effected by the Ragonet power gear and both high- and low-pressure valve motions are controlled simultaneously.

461. This gear is operated by compressed air and the air cylinder is placed on the right-hand side of the loco-

motive, immediately in front of the cab. Admission of air to this cylinder is controlled by a hand lever, convenient to the engineer; when this lever is set for any particular point of cut-off, the gear automatically locks itself in the corresponding position.

The piston of the air cylinder is directly connected to the high-pressure reverse shaft; the latter is coupled to the low pressure reverse shaft by a single reach rod, placed on the center line of the engine.

This reach rod is provided with a universal joint, so that it can accommodate itself to the position of the forward group of wheels when the engine is curving.

462. The hinge pin connecting the front and rear frames is 7 inches in diameter. It is placed on the center line of the engine, between the high-pressure cylinders and is inserted from below. The upper end of the pin has a bearing in the high-pressure cylinder saddle and the lower end in a cast steel cross tie which spans the lower rails of the rear frames.

The front frames are connected to the pin by a cast steel radius bar of most substantial construction.

463. The front frames are stopped immediately ahead of the leading driving pedestals, where they are securely bolted to the large steel box casting previously mentioned. To this casting is bolted the forward bumper beam, which is of cast steel 10 feet in length. The maximum width over the cylinder castings is approximately 11 feet.

464. The boiler is supported on the front frames by two bearings, both of which have their sliding surfaces normally in contact.

465. The front bearing carries the centering springs and the wear is taken in each case by a cast iron shoe, two inches thick.

466. Both bearings are fitted with clamps, to keep the frames from falling away when the boiler is lifted.

467. Westinghouse brake equipment is used and separate brake cylinders are provided for each group of driving wheels.

468. Air is supplied by two $8\frac{1}{2}$-inch cross compound compressors.

469. The cylinder cocks are operated by compressed air, as are the sanders. The rear group of wheels receive sand from a box placed over the boiler and the forward group from two rectangular boxes placed over the front deck plate.

470. These engines are practically equivalent to two consolidated type locomotives combined into one. They are handled much the same as an ordinary engine.

471. In order that full power may be developed in starting, it is necessary to admit steam direct from the boiler to the low-pressure cylinders. This is accomplished by opening the starting valve in the cab, thus admitting steam through a $1\frac{1}{2}$-inch pipe, to the receiver pipe leading from the superheater to the low-pressure cylinders.

472. As soon as the engine is under way and the high-pressure cylinders are exhausting into the receiver pipe, the starting valve should be closed and the engine worked entirely compound.

473. In the event of a break-down on the road, a locomotive of this type is handled in practically the same way

as an ordinary single-expansion engine. Either one of the high- or low-pressure main rods may be taken down and the engine run with three cylinders, provided the valve on the disabled side is placed in mid position.

474. In the event of cutting out one high-pressure cylinder, the starting valve should be left open. This will increase to some extent the power developed in the low-pressure cylinders. In all other respects the rules which apply to the care, operation, and break-downs of single-expansion engines apply as well to this one.

475. The Mallet engine is merely two single-expansion locomotives coupled together. One receives its supply of steam from the boiler and the other from the exhaust of the first engine.

476. The greatest feature of this locomotive is the changes which have been made in the construction of the boiler, which enables one boiler to do the work of and take the place of two.

477. General dimensions of the double consolidated Mallet type locomotive, class E–3.

Gauge	4 ft. $8\frac{1}{2}$ inches.
Cylinders	26 x 30 inches and 40 x 30 inches
Valves	Balanced Piston
Boiler Type	Straight
Diameter	84 inches
Working pressure	200 lbs.
Fuel	Coal
Fire Box Length	126 inches.
Width	$78\frac{1}{4}$ inches
Depth	front $75\frac{1}{2}$ inches, back $70\frac{1}{2}$ inches
Thickness of Sheets.	
Sides	$\frac{3}{8}$ inch.
Back	$\frac{3}{8}$ inch.
Crown	$\frac{3}{8}$ inch.
Tube	$\frac{1}{2}$ inch.
Tubes—Numbers	401
Diameter	$2\frac{1}{4}$
Length	21 ft. 0 inches.
Heating Surface	
Fire Box	232 sq. ft.
Tubes	4,941 sq. ft.
Feed Water Heater Tubes	1,220 sq. ft.
Total	6,393 sq. ft.
Grate Area	68.4 sq. ft.
Feed Water Heater Tubes.	
Number	401
Diameter	$2\frac{1}{4}$ inches
Length	5 ft. 3 inches.
Driving Wheels.	
Diameter outside	57 inches
Diameter center	50 inches.
Journals, main	11 x 12 inches.
Journals, others	10 x 12 inches

Engine Truck Wheels.
Diameter, front .... $30\frac{1}{2}$ inches.
Journals.................... 6 x 10 inches
Diameter, back .... $30\frac{1}{2}$ inches.
Journals.................... 6 x 10 inches.

Wheel Base.
Driving .... 39 ft. 4 inches.
Rigid........................ 15 ft. 0 inches.
Total Engine .... 56 ft. 7 inches.
Total Engine and Tender ... 81 ft. 6 inches.

Weight.
On Driving Wheels .... 394,150 lbs.
On Truck, front .... 14,500 lbs.
On Truck, back............ 17,250 lbs.
Total Engine .... 425,900 lbs.
Total Engine and Tender,
about.................... 596,000 lbs.

Tender.
Wheels, number .... 8.
Wheels, diameter .... 33 inches.
Journals.................... 6 x 11 inches.
Tank capacity .... 9,000 gallons.
Fuel capacity............... 10 tons.

Engine equipped with Baldwin smoke box superheater,
Superheating Surface ...... 655 sq. ft.

Part Four

AIR BRAKES

478. A brake is any device used for the purpose of retarding or stopping the rotation of the wheels of a vehicle.

479. A brake which is operated by manual labor is called a hand brake.

480. A brake which is operated by compressed air, steam, vacuum, hydraulic, or electric power is a power brake.

481. The hand brake and the power brake are usually combined on cars and locomotive tenders, but only the power brake is used on the engine.

482. An air brake is a mechanical brake system operated by compressed air.

483. The principal parts of the air brake system are:—
The air pump which compresses the air. The main reservoir which is used for storing, cooling, and draining the water and dirt out of the air.

The engineer's brake valve, which regulates the flow of air from the main reservoir to the train pipe for charging, supplying, and releasing the brakes. The necessary piping and hose coupling on the engine and tender and throughout the train.

The auxiliary reservoir, which is supplied with air from the train pipe through the triple valve. Air is thus stored in the auxiliary reservoir for use in applying the brakes on its own vehicle.

The triple valve, which is actuated by the variation of train pipe pressure is in turn regulated by the position of the engineer's brake valve and is used for setting and releasing the brakes upon its own vehicle.

The pump governor, which regulates the supply of steam to the air pump. The air gauge, which shows the main reservoir pressure and train line pressure.

The slide-valve feed-valve, which regulates the train pipe pressure when the engineer's automatic brake valve is in running position.

The reducing valve, which reduces the pressure admitted to the signal system and straight air brake valve.

The pressure retaining valve which is used to prevent a part or all of the air from being discharged from the brake cylinder, after an application of the brakes has been made and the brake valve is returned to release position for the purpose of recharging the train pipe and auxiliary reservoir.

Angle cocks, which are placed in the train pipe at the ends of the cars and the rear of the tender to prevent train pipe pressure from escaping when the hose couplings are disconnected.

Cut out cocks, which are placed in the different pipe connections on the engine and tender and in the branch pipe on each car and which are used for purposes hereinafter explained.

THE WESTINGHOUSE AIR BRAKE SYSTEM

484. The air pump is a small automatic engine and air compressor combined, its only dependence on the other parts of the locomotive being the steam which operates it.

485. The air which it compresses is used to operate the straight and automatic systems on the engine and tender and the automatic system throughout the train.

486. There are two systems of air brakes—the straight and the automatic.

487. With the straight air system the air compressed by the pump is stored in a large reservoir and when it is desired to apply the brakes, air is admitted to the train line and brake cylinders direct from the main reservoir, by means of a three-way cock.

488. When it is desired to release the brakes the three-way cock is turned so that air will escape through it from the brake cylinders and train line to the open air.

489. In the automatic system the air compressed by the pump is stored in the main reservoir, train line, and auxiliary reservoirs. When it is desired to apply the brakes a reduction of train line pressure is made by means of the engineer's automatic brake valve.

This reduction of pressure in the train line causes a movement of the triple valve, which admits air from the auxiliary reservoir to the brake cylinder, setting the brakes.

490. To release the brakes the engineer's brake valve is moved to release position, allowing air to flow from the main reservoir to the train line.

The increase of pressure in the train line forces the triple valves back to their normal position, allowing the pressure in each brake cylinder to escape to the open air.

491. The straight air system admits air to the train line to set the brakes and exhausts the air from the train line to release the brakes.

492. The automatic system exhausts air from the train line to set the brakes and supplies air to the train line to release the brakes.

493. The straight and automatic systems are sometimes combined on the locomotive and tender, by placing a double check valve in the junction of the automatic and straight air pipes to the brake cylinder pipe. They can thus be operated independently of each other, although attached to the same common system.

THE WESTINGHOUSE 9½-INCH AIR PUMP

494. The principal parts of the 9½-inch Westinghouse air pump are as follows:—

Steam Cylinder, 61; Air Cylinder, 63; Steam Piston and Head, 65; Air Head, 66; Main Valve, 83; Pistons, 77 and 79; Reversing Valve, 72; Reversing Rod, 71; Reversing Plate, 69; Inlet Valves, 86*a* and 86*b;* Discharge Valves, 86*c* and 86*d;* Drain Cock, 105; Oil Cock, 98; Air Strainer, 106; Reverse Valve Cap, 74. (Fig. 38.)

495. Steam from the boiler flows through passage *A* to chamber *A* above main valve 83 and between pistons 77 and 79 and through passage *C* to chamber *C* in which is reversing valve 72.

The supply and exhaust of steam to and from the steam

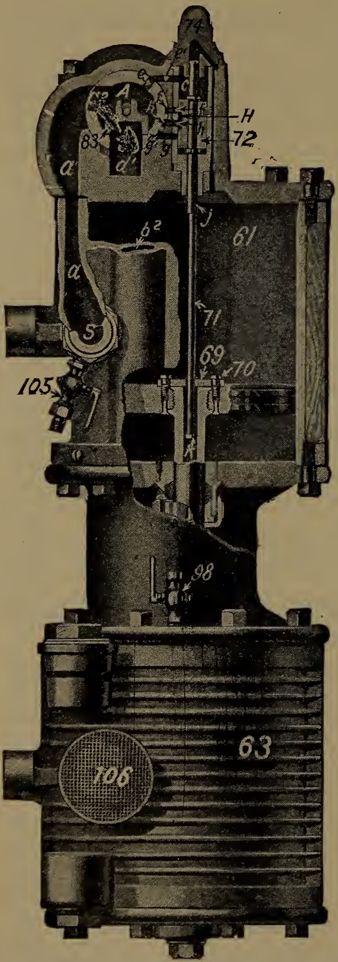


FIG. 38.—9½-Inch Air Pump, Showing Reversing Valve.

cylinder is controlled by the main valve 83 which is a D type of slide valve. It is operated by two pistons 77 and 79, of unequal diameters and connected by stem 81.

The movement of these two pistons and valve 83 are controlled by reversing valve 72, which is in turn operated by the main steam piston 65 by means of the reversing rod 71 and the reversing plate 69.

When steam enters chamber *a* main slide valve 83 and pistons 77 and 79 are moved to the right, uncovering passage *B* in the valve seat and permitting steam to flow through passage *B* and *B*-2, which leads to the bottom of the steam cylinder under the main steam piston head, forcing it upward.

When steam piston 65 is at the bottom of the cylinder, reversing plate 69 has engaged the button on the end of reversing rod 71 and moved reversing valve 72 to its lower position.

Chamber *D* is now connected with main exhaust passage *D* through ports *H* reversing valve exhaust cavity *H* and ports *F F*.

Therefore as chamber *E* at the left of piston 79 and chamber *D* at the right of piston 77 are both connected to the exhaust, steam in chamber *A*, exerting the greater pressure against piston 77 moves it to the right, moving main slide valve 83 with it. The main valve 83 is now admitting steam below piston 65, forcing it upward, and steam above piston 65 is exhausted through ports *C* exhaust cavity *B* in main valve 83 and ports *D D* to the exhaust. As the piston is forced upward the reversing plate 69, coming in contact with the shoulder on reversing rod 71, raises it, moving reversing valve 72 to the upper end of its stroke, uncovering port *G*.

Steam from chamber *C* then enters chamber *D* through ports *G G* of the bushing. The pressure upon the two sides of piston 77 is thus equalized or balanced. There is no pressure except exhaust steam in chamber *E* and piston 77, being balanced, steam in chamber *A* forces piston 79 to the left, permitting steam to flow from *A* to *C* on top of piston 65.

496. The air end of the pump is operated by means of the piston rod 65 and air piston 66.

When the piston in the air cylinder is moved upward by the action of the steam in the steam cylinder, a vacuum is created below the piston head 66.

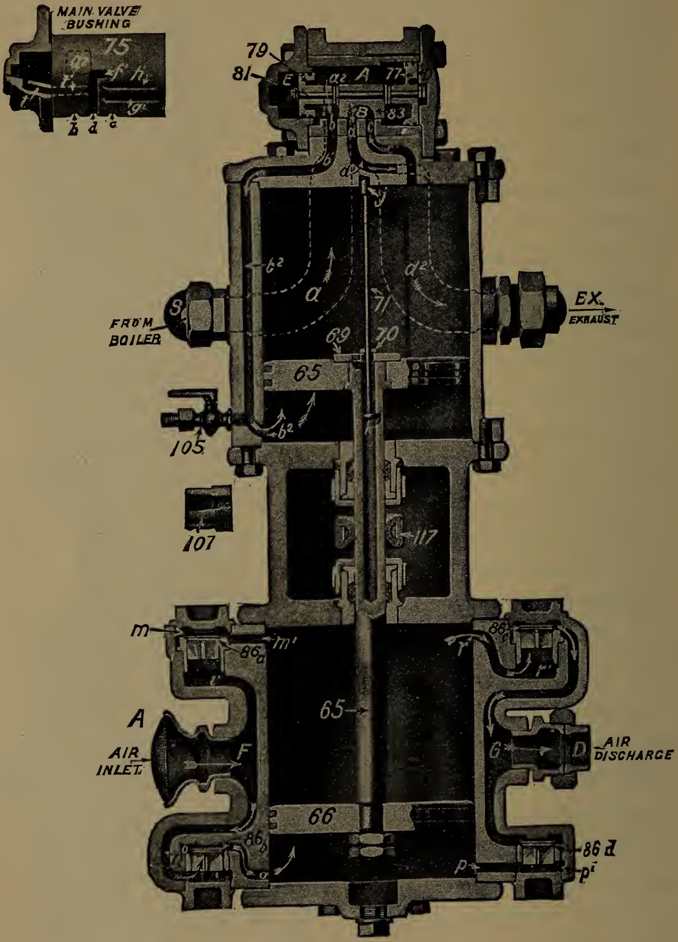


FIG. 39.—9½-inch Air Pump, Showing Main Valve.

The atmospheric pressure now lifts the lower supply valve 86*b*, rushing into the cylinder to supply the vacuum created when the piston starts on the return stroke. The air thus drawn into the cylinder will be forced through the bottom discharge valve 86*d* into the main reservoir.

At the same time air is rushing into the cylinder through the top receiving valve 86*a*. This air will be compressed and forced into the main reservoir through the top discharge valve 86*c* on the upward stroke.

WESTINGHOUSE 8½-INCH CROSS COMPOUND COMPRESSOR

497. In general construction the 8½-inch compound compressor consists of two steam and two air cylinders. The steam cylinders, one high-pressure and one low-pressure forming the top and one high-pressure and one low-pressure air cylinder forming the bottom part.

The high-pressure steam piston and the low-pressure air piston are joined by one piston rod, while the low-pressure steam piston and high-pressure air piston are joined by one rod.

The high- and low-pressure steam pistons are both actuated by one piston valve, placed in the top head of the compressor. This valve is constructed with a large head on the right-hand end and a small head on the left-hand end with three intermediate piston heads of a uniform size. This piston valve is in turn controlled by a reversing valve 22 and reversing rod 21.

THE STEAM END

498. The steam which operates the high-pressure steam piston is exhausted into the low-pressure steam cylinder, where it expands and operates the low-pressure steam piston.

Steam enters through passage *a*, chamber *b*, and passage *g*, to the lower end of the high-pressure steam cylinder, forcing the high-pressure steam piston and low-pressure air piston upward.

When the high-pressure steam piston 7 completes its upward stroke, reversing valve plate 18 engages the shoulder on reversing rod 21, forcing it upward, moving reversing valve 22 covering the port to passage *m*, stopping the exhaust of steam from chamber *d*, at the same time uncovering the port to passage *n*, permitting live steam to flow from passage *a* to chamber *d*. The steam pressure is now equalized on both sides of the large piston head and the pressure against the right side of the small piston head 25 moves the valve to the left, admitting steam to the top of the high-pressure steam cylinder and forcing the piston downward. The steam from below piston 7 is now being exhausted through passage *g*, cavity *i*, and passage *f* into the lower end of the low-pressure steam cylinder, forcing piston 8 upward. The steam on top of piston 8 is exhausted to the atmosphere through passage *d*, cavity *h*, and passage *E*.

The high-pressure steam piston in completing its downward stroke, the reversing plate 18 engages the button on

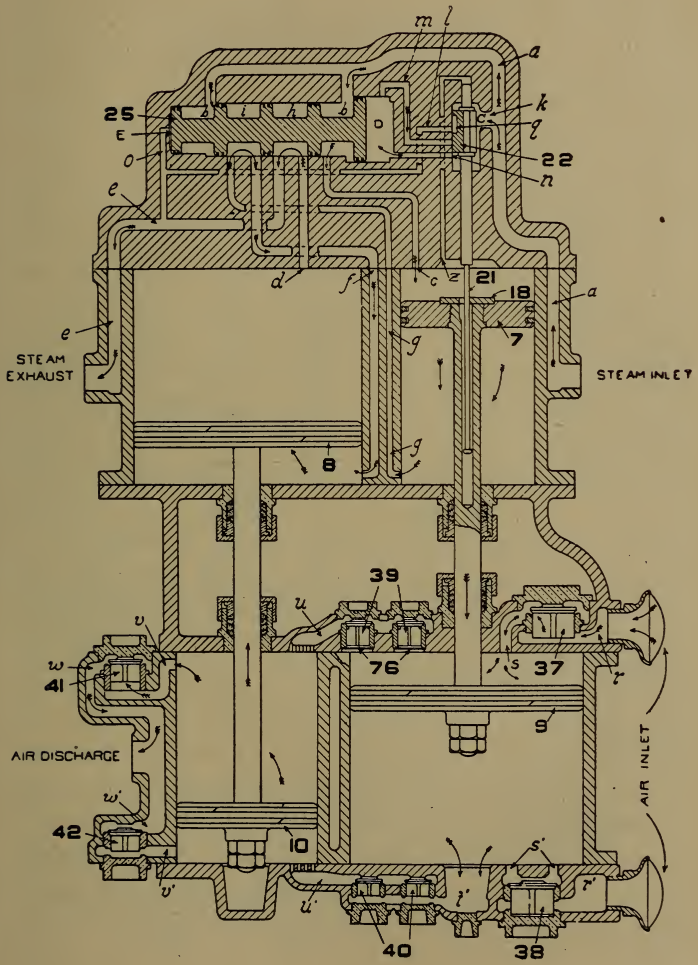


FIG. 40.—8½-Inch Cross Compound Compressor, Up Stroke.

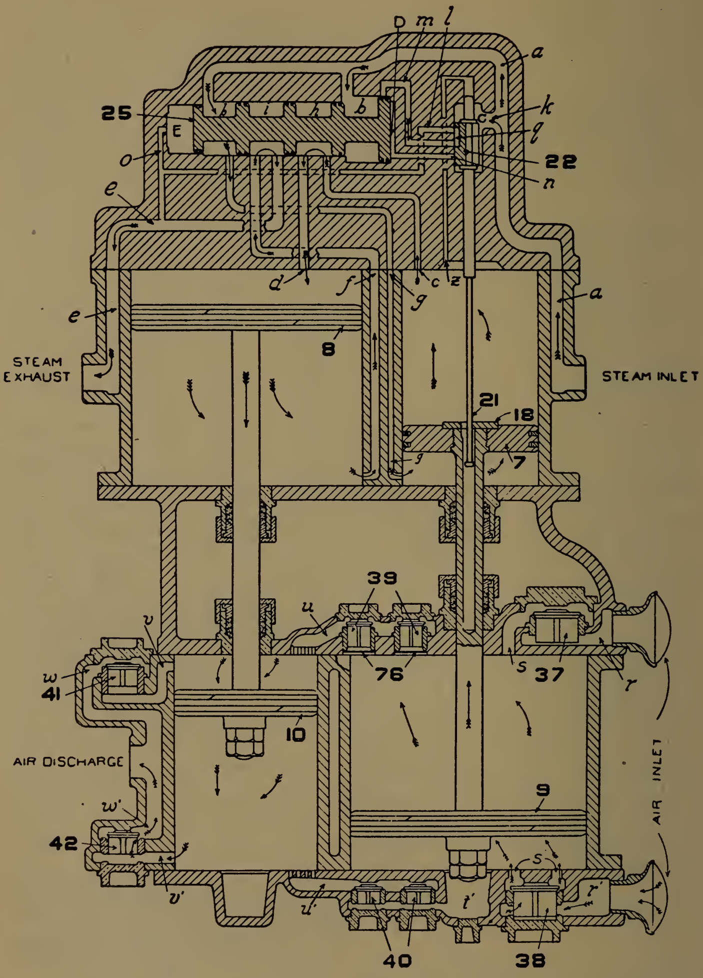


FIG. 41.—8½-Inch Cross Compound Compressor, Down Stroke.

the end of reversing rod 21, pulling it down, moving reversing valve 22 to its lower position, closing the port leading to passage *n*, shutting off the supply of live steam, and connecting passage *m*, cavity *q*, and passage 1, exhausting the steam from cavity *d*. There now being no pressure at the outer ends of the valve the pressure against the inside of the right-hand head being greater than that against the inside of the left-hand head, the valve is moved to the right and the reverse movement again takes place.

Just as the low-pressure steam piston has completed its upward stroke steam is by-passed through three by-pass grooves from the lower to the upper side of the low-pressure steam piston, thereby preventing an accumulation of back pressure in the lower end of the high-pressure cylinder. This also occurs at the opposite end of the stroke as described:

499. The Air End.—When the low-pressure air piston 9 is moved upward a vacuum is created in the lower end of the cylinder and atmospheric air rushes in through air inlet *r*, raising valve 38 to fill the space below the piston. At the same time piston 9 is forcing the air above it through the intermediate valves 39, into the upper end of the high-pressure air cylinder. As the movement of the pistons reverses, the air which was drawn into the cylinder by piston 9 is compressed and forced through intermediate valves 40 into the bottom of the high-pressure air cylinders and atmospheric air is supplying the space in the upper end of the low-pressure cylinder through inlet valve 37.

The air which was forced into the high-pressure air cylinder on the upward stroke of the low-pressure piston, is compressed and forced through passage *v*, discharge valve 41, and passage *w*, to the discharge pipe and main reservoir. The air which was forced into the lower end of the high-pressure cylinder by the downward stroke of the low-pressure piston will now be compressed and forced out through passage *v*, valve 42 and passage *w*, to the exhaust and main reservoir, by the return stroke of the high-pressure piston.

500. The 8½-inch cross compound compressor has a capacity over three times greater than the 9½-inch pump, while the steam consumption per cubic foot of air compressed is but one-third.

AIR PUMP GOVERNORS

501. An air pump governor is an automatic power valve used for controlling the admission of steam to the air pump.

502. There are several designs of air pump governors, but the designs in most general use are the single-top governor and the double-top governor known as the S-F 4.

503. The governor is placed in the main steam supply pipe to the air pump.

504. The Single Top Governor: The pipe connections are (see right-hand head, Fig. 42):

B. steam supply pipe connection to the boiler.

P. is the steam pipe connection to the air pump.

M R. is the main reservoir air pressure connection.

505. When the *D* 8 brake valve is used *M R* is connect-

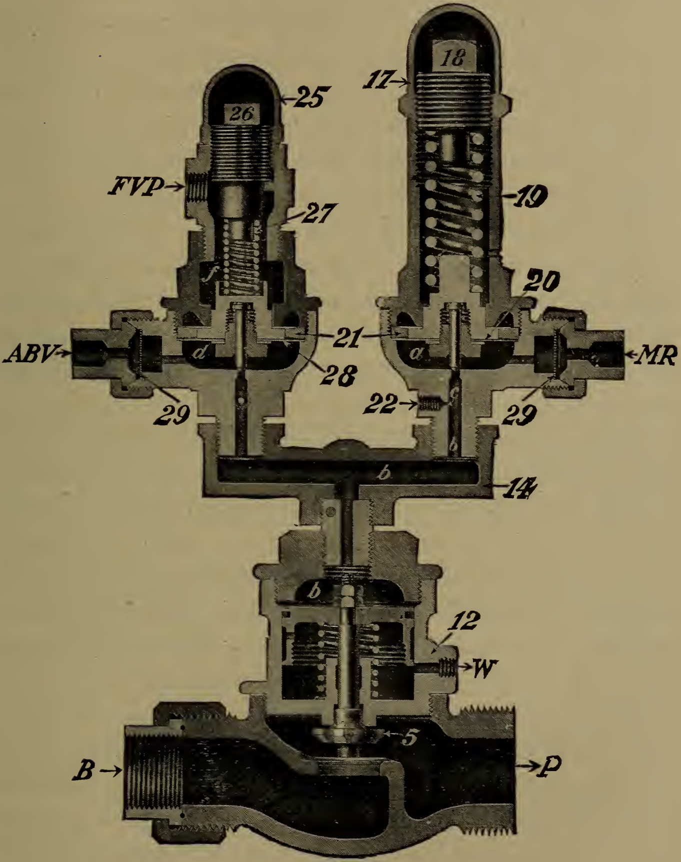


FIG. 42.—S F-4 Pump Governor.

ed to train pipe pressure instead of main reservoir pressure.

506. The adjustment of the governor is accomplished by means of adjustment nut 18, which regulates the tension of adjustment spring 19 upon diaphragm 20. While the tension of spring 19 is greater than the air pressure exerted in chamber *a*, against the underside of diaphragm 20, it holds the small pin valve *d* to its seat.

507. When the air pressure in chamber *a* becomes greater than the tension of adjustment spring 19, diaphragm 20 will be raised, unseating the small pin valve *d*, permitting air from chamber *a* to flow into the chamber above piston 6, forcing it down, seating steam valve 5, stopping the flow of steam to the air pump.

When the air pressure in the main reservoir falls below the pressure at which the adjustment spring 19 is set to maintain, spring 19 will force diaphragm 20 down, seating pin valve *d*.

The air in the chamber above piston 6 is then exhausted through vent port *c*. Piston 6 is now raised by spring 9 and the steam pressure under valve 5 opens it, permitting steam to flow from the boiler to the air pump.

During the time that pin valve *d* is unseated and steam valve 5 is closed, there is a continuous leakage of air through vent port *c*. At the same time steam is flowing through a small port in valve 5 to the air pump. This steam causes the pump to operate slowly, supplying the air leakage from vent port *c*, keeping the air pump warm and free from condensation.

A drip pipe is connected at *x* to the chamber immediately below piston 6, for the purpose of permitting any steam that may leak past piston 6 to escape to the atmosphere.

THE S F AIR PUMP GOVERNOR

508. The S F pump governor is constructed with two regulating heads and one operating steam valve.

509. The reason for having two regulating heads on this governor is that during most of the time on a trip the brake valve is in running position and a high excess pressure is not desirable, but when the brakes are applied and a higher excess pressure is desired to release and recharge the train line, then the pump will start and pump up from ten to twenty pounds more of excess pressure.

510. The excess pressure head is adjusted to stop the pumps at the minimum excess pressure desired in the main reservoirs, while the automatic brake valve is in running, release, or holding positions.

511. The maximum pressure head is adjusted to stop the pumps at the maximum pressure desired in the main reservoirs, when the automatic brake valve is in the service, lap, or emergency position.

512. The maximum pressure head of the S F governor is just the same as the single top governor. The tension of the regulating spring 19 is adjusted at about 110 pounds for freight service and 140 pounds for passenger service.

513. The difference in the construction of the excess pressure head from that of the maximum pressure head is, that feed valve pressure is admitted through connection

F V P to the top of the governor head around adjustment spring 27 above diaphragm 28.

514. The tension of adjustment spring 27 is adjusted at 30 pounds. Therefore if the feed valve pressure is 70 pounds and the tension of the spring 30 pounds the combined pressure on top of diaphragm 28 will be 100 pounds. Thus the pressure on top of diaphragm 21 will hold the small pin valve to its seat, until the main reservoir pressure is equalized through its connection with the main reservoir (through the automatic brake valve, while the brake valve is in release, running, or holding positions). When the reservoir pressure slightly exceeds the combined pressure of the feed valve and the tension of the adjustment spring, it will raise the diaphragm and pin valve, allowing air to flow to chamber *b* above the governor piston, forcing the latter downward, compressing its spring, and closing steam valve 5.

When main reservoir pressure in chamber *d* becomes reduced the combined spring and air pressure above the diaphragm 28 forces it down, seating its pin valve.

As chamber *b* is always open to the atmosphere through small vent port *c*, the pressure in chamber *b* above the governor piston will then escape to the atmosphere. As there is now no pressure on top of the governor piston it will be raised by the combined tension of the spring under it and the steam under valve 5, raising valve 5 from its seat and permitting steam to flow to the pump.

The main reservoir connection through the automatic brake valve to chamber *d* is open only when the automatic brake valve is in release, running, or holding positions. In all other positions the flow of reservoir air to this governor head is cut out.

515. The maximum pressure head connection marked *M R* is connected to main reservoir pressure and is always in direct communication with the main reservoirs.

516. When the excess pressure head is cut cut by moving the handle of the automatic brake valve to the right of holding position, the maximum pressure head will control the pump. As the maximum head is now in control and its adjustment spring 19 is adjusted at a tension of 10 pounds more than the combined air and spring pressure in the excess pressure head, the pin valves in both governor heads are now held to their seats, allowing steam valve 5 to open and steam to flow to the pump.

When main reservoir pressure in chamber *a* exceeds the tension of adjustment spring 19 diaphragm 20 will raise its pin valve, allowing air to flow to chamber *b*, above the governor piston, closing valve 5, and stopping the flow of steam to the pump.

517. There is a small port in steam valve 5, the same as that in the steam valve of the single-top governor through which steam flows to the pump, operating it slowly, to keep it warm and prevent an excess of condensation from gathering in the pump.

518. Each governor head has a small vent port *c*, from which air escapes to the atmosphere whenever present in chamber and passage *b*. To prevent the unnecessary waste of air at times when it is necessary to maintain a pressure in this chamber, one of these ports should be plugged.

519. To adjust the excess pressure head of the S F

pump governor, place the automatic brake valve handle in running position, then remove cap nut 25 and turn adjusting nut 26 until the tension of spring 27 gives the desired difference between main reservoir and brake pipe pressures.

520. To adjust the maximum pressure head, place the automatic brake valve handle on lap position, then remove cap nut 17 and turn adjusting nut 18 until the tension of spring 19 causes the governor to stop the pump at the maximum main reservoir pressure desired.

ENGINEER'S BRAKE VALVES

THE STRAIGHT AIR BRAKE VALVE OR THREE-WAY COCK

521. This brake valve is the most simple of any of the devices used for the control of compressed air on the locomotive.

522. It is called a three-way cock because it does three things.

523. First, it applies the brakes by permitting reservoir air to flow direct from the main reservoir to the brake cylinders.

Second, it holds the air in the brake cylinders until it is desired to release it.

Third, it releases the air from the brake cylinders to the atmosphere. The position of the ports in the three-way straight air valve are indicated by marks on top of the plug.

524. When the handle is turned to the right communication is established between the main reservoir and the brake pipe to the brake cylinders.

525. When the valve is turned to the left the flow of air from the main reservoir to the train line is cut off and the air which was admitted to the train line and brake cylinders is held there until the handle of the valve is moved a little farther to the left, then communication is established from the train line and brake cylinders to the atmosphere through the brake valve.

THE COMBINED AUTOMATIC AND STRAIGHT AIR BRAKE

526. The combined automatic and straight air brake is a device by which either the automatic or straight air valves may be used to apply the brakes on the engine and tender.

527. The pressure to operate the straight air brake is taken from the main reservoir which supplies the pressure to the automatic system. A reducing valve is placed in the supply pipe between the main reservoir and the straight air valve; this reducing valve is adjusted at 45 pounds which is the maximum pressure that can be placed in the brake cylinders by the use of the straight air valve.

528. A double-seated check valve is placed in the pipe connections of the automatic and straight air systems between the triple valve and the brake cylinder, so that when either the automatic or straight air is used it will have to pass through the double-seated check valve to and from the brake cylinder.

529. When the automatic valve is used, air from the triple valve entering the double-seat check valve forces it

to the right, closing the straight air ports, preventing any escape of air through the straight air valve, and at the same time opening the ports at the automatic end of the valve, permitting air to flow directly to the brake cylinder.

530. When making either an automatic or straight air application, the double seated check valve will automatically move to the proper position.

531. The parts of the straight air portion of this combined brake equipment are: The engineer's straight air brake valve. The reducing valve. Double-seated check valves. Safety valve and special hose connection.

532. The safety valve is used for the purpose of reducing the excess pressure in the brake cylinder and train line, when from any cause the pressure in the brake cylinder exceeds the maximum pressure desired.

AUTOMATIC BRAKE VALVES

533. The automatic brake valve contains three valves. They are:

534. First, the rotary valve which is operated by the brake valve handle, the movement of which causes the ports, passages, and cavities in the rotary valve to register in a predetermined manner with the ports in the valve seat.

535. Second, the equalizing discharge valve which is actuated by the movement of the rotary valve and automatically controls the flow of air from the brake pipe to the atmosphere in making a service application of the brakes.

536. Third, the feed valve which automatically con-

trols the pressure admitted to the brake pipe when the brake valve is in running position.

537. To apply the brakes to make an ordinary stop, move the brake valve handle from running to service position; after a sufficient reduction is made return handle to lap position (which covers all ports), and hold there until it is desired to make a further reduction of train line pressure or to release the brakes.

538. If it is desired to make a further application of the brakes return the brake valve handle to service position, but if it is desired to release the brakes, move the brake valve handle to release position where it may be left long enough to insure the full release of all the brakes, then return to running position to prevent overcharging the train line.

539. To apply the brakes in the emergency position, move brake valve handle as far to the right as it will go and leave it in that position until the train has come to a full stop.

540. In the emergency position the train line and auxiliary pressures are at once combined in the brake cylinders, causing the pressure in the brake cylinders to be considerably in excess of that obtained by the service application.

541. As the train line and auxiliary pressures are the same, the higher pressure is obtained in the brake cylinders by the emergency application on account of the large volume of air in the train line and its instantaneous admission to the brake cylinder, where it joins the air from the auxiliary reservoir, thereby raising the pressure in the

brake cylinder above that obtained by the service application.

542. When the brake valve handle is in full release the air feeds directly from the main reservoir through the brake valve to the train line.

543. When the brake valve is in running position, the air passes through the feed valve attachment which automatically shuts off the flow of air to the train line or brake pipe when it has reached a pressure of 70 pounds in freight service and 110 pounds in passenger service.

THE G-6 TYPE OF ENGINEER'S BRAKE VALVE

RELEASE POSITION

544. When the brake valve handle is in release position, main reservoir pressure entering the brake valve at *M R* through passage *a*, fills the cavity above the rotary valve 14, holding it to its seat; air will now pass through port *a*, in the rotary valve cavity *b*, in its seat then through cavity *c*, in the rotary valve and down through port 1,1, to the train pipe under equalizing piston 18.

At the same time air is passing through port *j* in the rotary valve and *e* in its seat to cavity *d*, air is also flowing through port *a*, in the rotary cavity *b*, in its seat cavity *c*, in the rotary and port *g* in its seat to cavity *d*, thus equalizing the pressure on equalizing piston 18, holding it to its seat. Port *r* in the rotary valve is now in register with the direct exhaust passage; main reservoir pressure thus flowing to the atmosphere makes a warning sound to notify the engineer that the brake valve is in full release position.

If the brake valve is allowed to remain in the full release position the brake pipe will become overcharged, the train pipe and main reservoir pressures equalizing.

In order to prevent the overcharging of the train pipe,

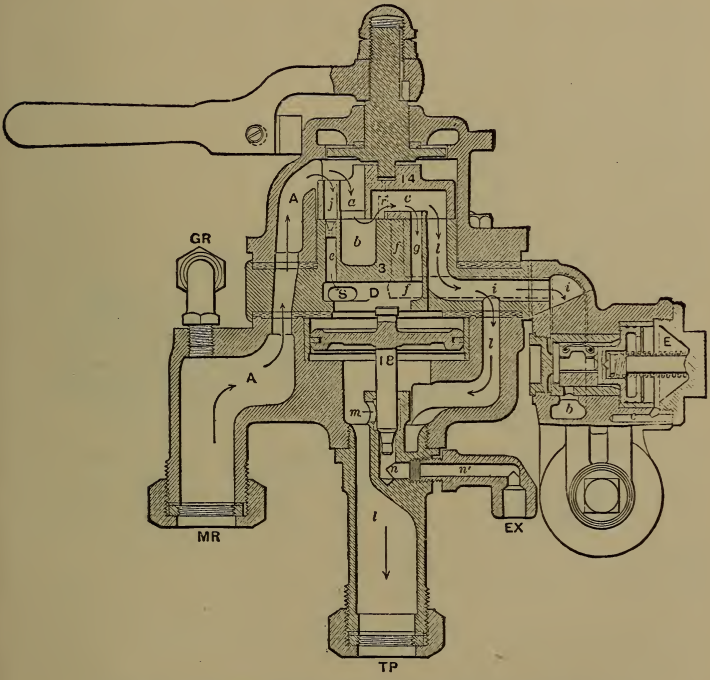


FIG. 43.—Release Position G-6 Automatic Brake Valve.

the brake valve handle must be moved to running position.

Cavity *d* above the equalizing piston is always in direct communication with the equalizing reservoir; therefore pressure and volume of air in cavity *d* are always the same as that in the equalizing reservoir.

The equalizing reservoir is thus connected to cavity *d* for the purpose of increasing the volume of air on top of

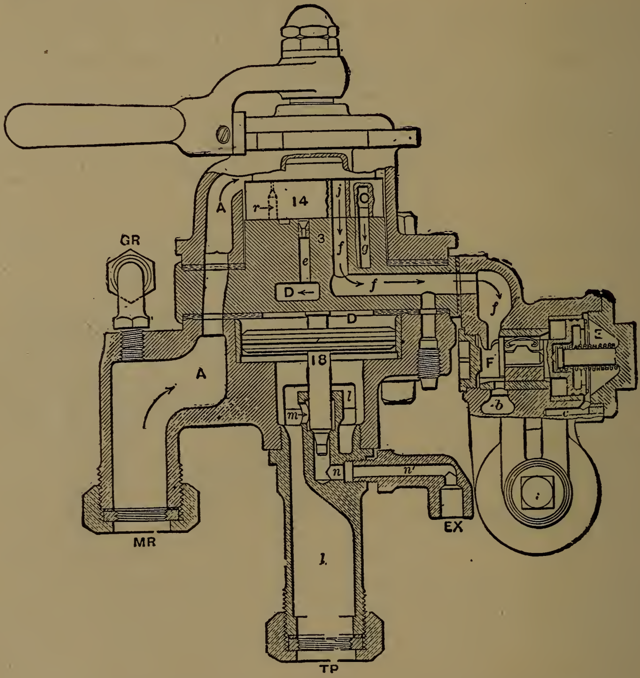


Fig. 44.—Running Position G-6 Automatic Brake Valve.

equalizing piston 18, so that in making service applications of the brake, a more uniform and gradual reduction can be made than would be possible with the small volume of air contained in cavity *d* alone.

RUNNING POSITION G-6 TYPE

545. Main reservoir pressure is always present on top of rotary valve 14.

When the brake valve handle is in running position main reservoir pressure passes down through port *j* in the rotary valve to port *f* in the seat, thence through *f* and *f* to the slide valve feed valve attachment, then through the slide valve feed valve to the train pipe, below equalizing piston 18. At the same time cavity *c* in rotary valve 14 is over port *g* (in the rotary seat) which leads to chamber *d*; causing the pressure to be equal above and below the equalizing piston 18.

SERVICE APPLICATION POSITION G-6 TYPE

546. When the brake valve handle is placed in service application position, all ports permitting main reservoir pressure to pass through the brake valve are closed.

At the same time a small groove in the face of rotary valve 14 has opened communication between ports *e* and *k* in the rotary seat.

Port *e* leads to chamber *d* above equalizing piston 18.

Port *k* leads to the exhaust passage. Air is then permitted to flow from chamber *d* and the equalizing reservoir to the atmosphere, reducing the pressure on top of equalizing piston 18. The train pipe pressure below equalizing piston 18 now being greater than that above it, the piston is moved upward, unseating its stem, permitting air from the train pipe to flow through port *m,n,n,* to the train pipe exhaust *e x.*

When sufficient air has been exhausted from the train pipe, to slightly reduce the train pipe pressure on the

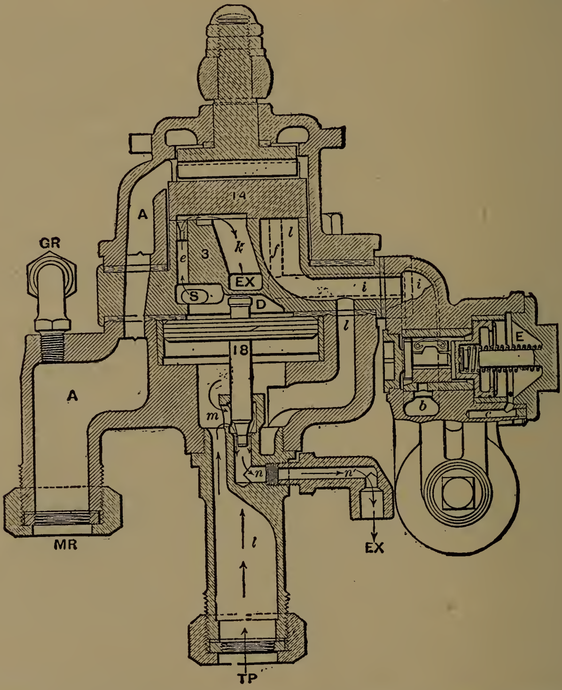


FIG. 45.—Service Application G-6 Automatic Brake Valve.

underside of equalizing piston 18 below the pressure remaining in chamber *d*, equalizing valve 18 will be forced to its seat by the greater pressure in chamber *d*, thus shutting off the train pipe exhaust.

LAP POSITION G-6 TYPE

547. When the brake valve handle is in lap position, all ports are closed, there being no passage of air either to or from the train pipe.

EMERGENCY POSITION G-6 TYPE

548. When the brake valve handle is placed in the emergency position, ports 1 and 1 cavity *c* and main exhaust port *k* are placed in direct communication with each other, permitting train pipe pressure to flow directly to the atmosphere. At the same time chamber *d* and the equalizing reservoir are opened to the atmosphere through preliminary exhaust port *e*, a small groove in the rotary valve and groove *h* in its seat, which leads to exhaust port *k*. When an emergency application of the brake is made equalizing piston 18 does not move and there is no exhaust from the train pipe service exhaust port. The reduction of train pipe pressure through the direct application and exhaust port is so great that the pressure is instantly reduced below piston 18. The pressure in chamber *d* being exhausted through the preliminary exhaust port, is exhausted much slower than the train pipe pressure, thus the greater pressure in chamber *d* holds equalizing piston 18 to its seat.

THE E T LOCOMOTIVE BRAKE EQUIPMENT

549. The Westinghouse E T locomotive brake equipment was first introduced in 1905, since which time it has been considerably changed and improved.

550. The two designs of the E T locomotive brake equipment which are now in use are designated as the No. 5 E T equipment and the No. 6 E T equipment.

The No. 6 E T equipment is a modification of the No. 5,

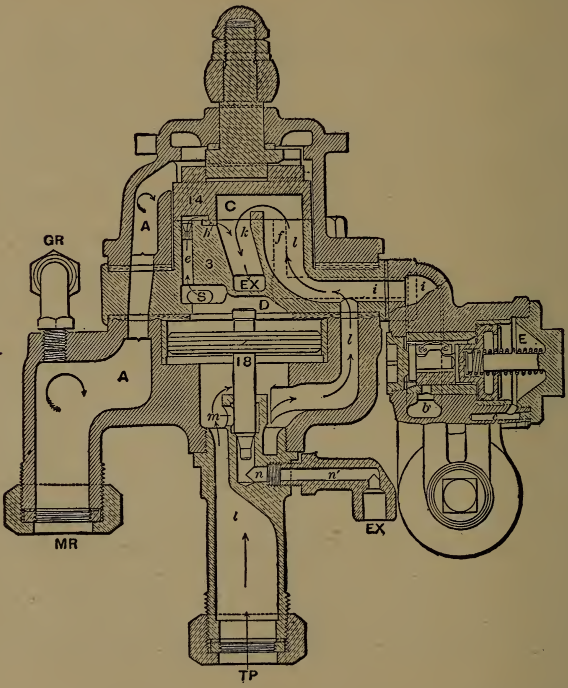


Fig. 46.—Emergency Application G-6 Automatic Brake Valve.

to accomplish the same results by simpler means, as well as to embody certain other advantageous features.

551. The only difference in manipulation between the No. 5 and the No. 6 equipment is that on the second

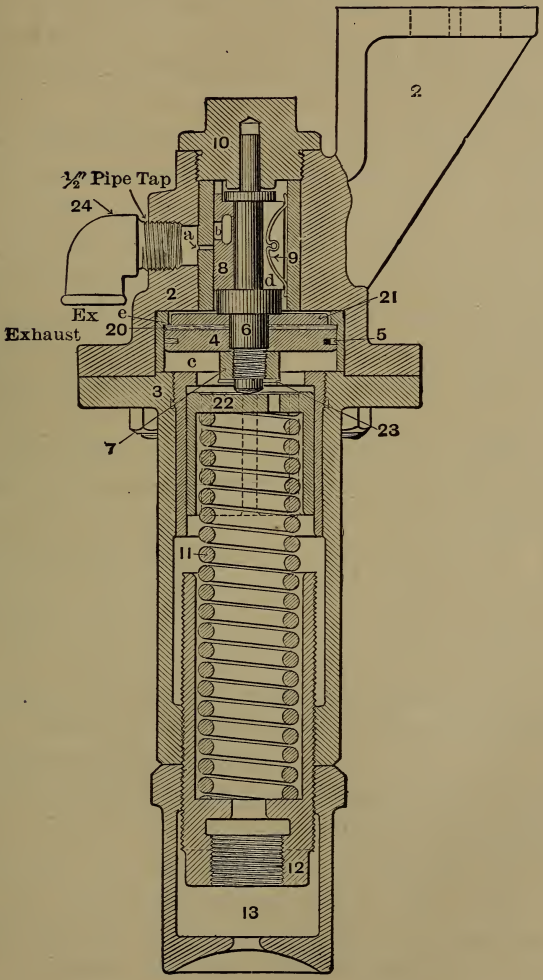


Fig. 47.—Automatic Reducing Valve.

engine in double heading the No. 6 brake valve handle remains in running position, as with the old standard G–6 brake valve, instead of in lap position as with the No. 5 equipment.

552. One of the advantages of this equipment is that the brake valves can be taken apart for repairing or cleaning without removing any of the pipe connections.

553. The automatic brake valve used with the E T equipment has one more position than the G–6 type, called holding position. This position is placed just between running and lap and is used for holding the brakes applied on the engine and tender while the train brakes are released and the auxiliary reservoirs recharged.

554. This action is accomplished by means of a distributing valve and double chamber reservoir to which it is attached.

555. The distributing valve and double chamber reservoir takes the place of and does away with the triple valves and auxiliary reservoirs, high-speed reducing valves and double check valves on the engine and tender.

556. It is through the distributing valve that the straight or independent and automatic brakes are united.

557. When the brakes are applied automatically, they can be released or applied on the locomotive by means of the independent brake valve.

558. On long grades where the tires are liable to become heated, the brakes can be released on the locomotive until it is necessary to release the train brakes, then the independent brake may be applied to hold the slack in the train until the train pipe and auxiliary

reservoirs are recharged, ready for another application of the brakes.

559. When the brakes are applied by the independent brake valve, they remain set until released by the brake valve. The distributing valve automatically supplies the leakage and maintaining the same pressure in the brake cylinders as when first applied.

560. This is a very important safety feature, especially with light engines, when taking water and coal at water plugs and coaling stations. When leaving the engine to do work about it, or if for any cause it is necessary to leave the engine, always leave the independent brake valve handle in application position.

561. The independent brake valve is not intended to be used in stopping long trains and must not be so used, as the sudden bunching of long trains may cause damage to the cars or lading.

PIPING OF THE E T NO. 6 EQUIPMENT

By referring to piping instruction diagram Figs. 48–49, all the pipes may be traced and the piping of the E T equipment easily understood.

562. Beginning at the discharge from the air pump; the air passes to the right-hand main reservoir, thence through reservoir connecting pipe to the left-hand main reservoir, then through main reservoir pipe to the automatic brake valve. A cut out cock is placed in the main reservoir pipe, for the purpose of venting the air from the pipe when removing any of the apparatus except the gov-

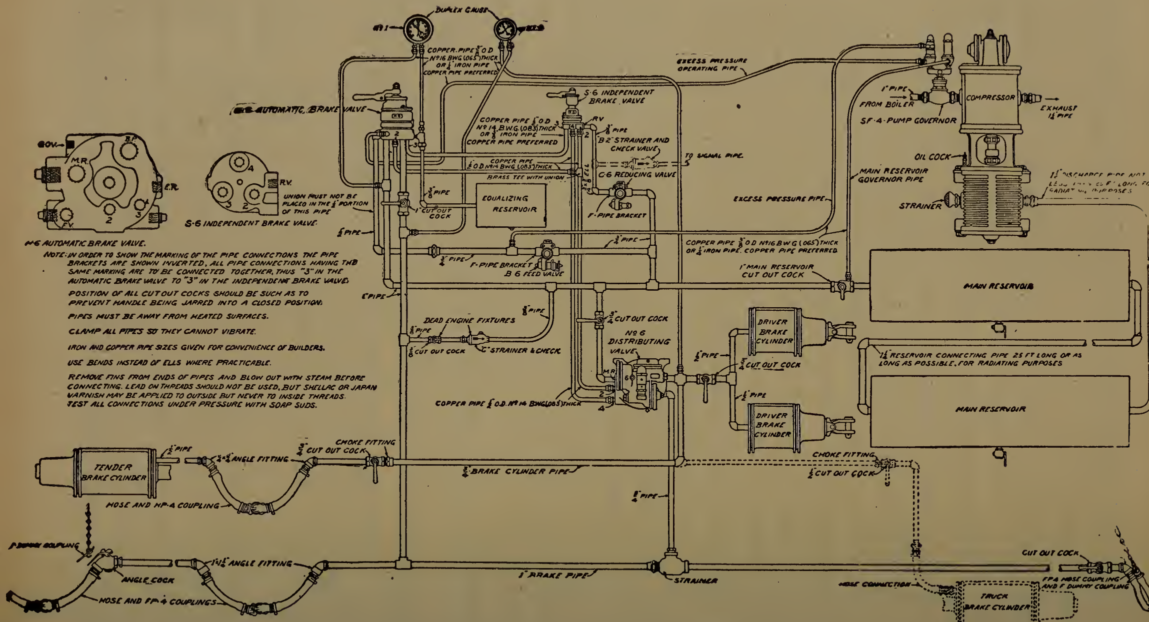


FIG. 48.—Piping Diagram of the No. 6 E T Equipment.

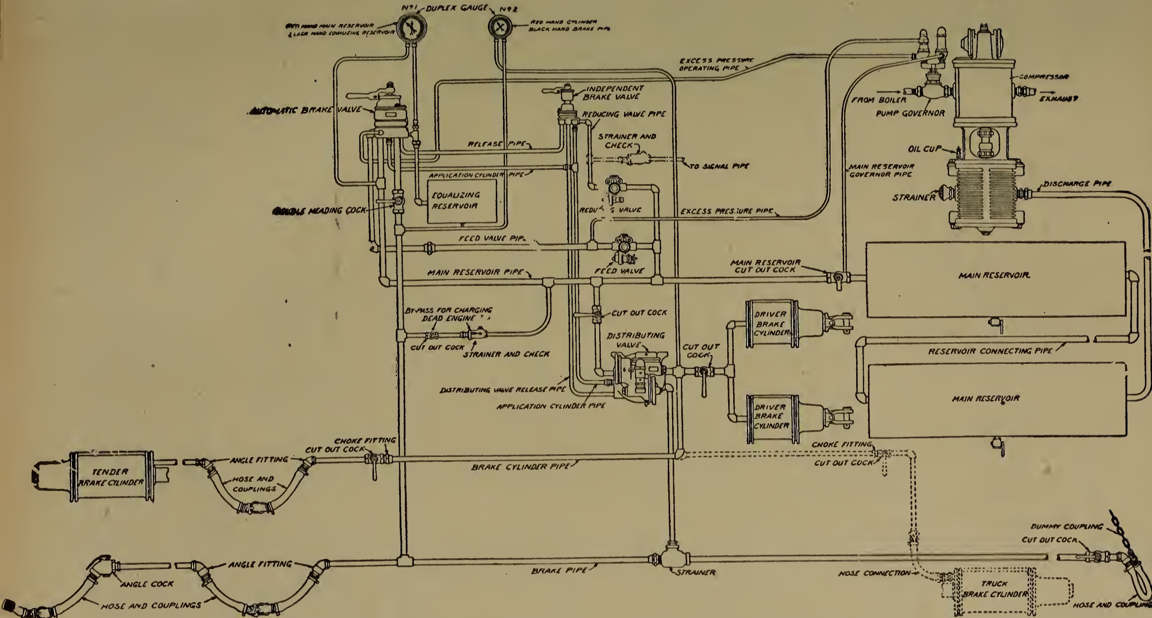


FIG. 49.—Instruction Diagram of the No. 6 E T Equipment.

ernor. The end of this cut out cock next the reservoir is tapped for a connection to the pump governor.

563. Before this cock is closed, the double heading cock should be closed and the brake valve handle placed in release position. This is to prevent the slide valve of the feed valve and the rotary valve of the brake valve being lifted from their seats.

564. Beyond the main reservoir cut out cock the main reservoir pipe has four branches, one of which runs to the automatic brake valve, one to the feed valve, one to the reducing valve and one to the distributing valve.

565. As a result the automatic brake valve receives air from the main reservoir in two ways, one direct and the other through the feed valve.

566. The feed valve pipe, from the feed valve to the automatic brake valve, has a branch to the top of the excess pressure head of the duplex pump governor.

567. The third branch of the main reservoir pipe connects with the reducing valve. Air at the pressure for which this valve is set (45 pounds) is supplied to the independent brake valve through the reducing valve pipe.

568. When the air signal system is installed, it is connected to the reducing valve pipe, in which case the reducing valve also takes the place of the signal reducing valve formerly used.

569. In the branch pipe supplying the air signal system is placed a combined strainer, check valve, and choke fitting. The strainer prevents any dirt from reaching the check valve and choke fitting. The check valve prevents

air from flowing back from the signal pipe when the independent brake valve is applied.

570. The choke fitting prevents the reducing valve from raising the signal pipe pressure so quickly as to destroy the operation of the signal.

571. The distributing valve has five pipe connections made through the end of the double chamber reservoir, three on the left and two on the right as shown in Figs. 53 and 54. Of the three on the left the upper one is the supply from the main reservoir, the intermediate is the application cylinder pipe leading to the independent and automatic brake valves. And the lower one is the distributing valve release pipe, leading through the independent brake valve (when the handle is in running position) to the automatic brake valve.

Of the two on the right, the lower one is the brake pipe branch connection and the upper one is the brake cylinder pipe connection to all the brake cylinders on the engine and tender.

572. In this pipe are placed cocks for cutting out the brake cylinders when necessary. In the engine truck and tender brake cylinder cut out cocks are placed choke fittings to prevent serious loss of main reservoir air and the release of the other locomotive brakes during a stop, in case of burst brake cylinder hose.

573. The two duplex air gauges are connected as follows:—Gauge No. 1; Red Hand to main-reservoir pipe under the automatic brake valve.

574. Black Hand, to equalizing reservoir pipe tee of the automatic brake valve.

575. Gauge No. 2; Red Hand, to the brake cylinder pipe; Black Hand, to the brake pipe below the double-heading cock.

576. The amount of reduction made during an auto-

Fig. 50.—Large Duplex Gauge, No. 1.

Fig. 51.—Small Duplex Gauge, No. 2.

matic application is indicated by the Black Hand of Gauge No. 1.

577. The Black Hand of Gauge No. 2 is to show the brake pipe pressure when the engine is second in double heading, or a helper.

578. The automatic brake valve connections, other than those already mentioned are the brake pipe, the equalizing reservoir, and the lower connection to the excess-pressure head of the pump governor.

THE DEAD ENGINE FEATURE

579. A dead engine feature is provided in the piping of the E T equipment as shown in Fig. 48. This feature is used on a locomotive in a train when the engine is dead,

or from any reason its air pumps are inoperative. A combined strainer and check valve with choke fittings are provided in this pipe, as this feature is only used for supplying the air to the main reservoirs of a locomotive; to operate its brakes under the conditions just mentioned, the air must be supplied by the locomotive operating the train.

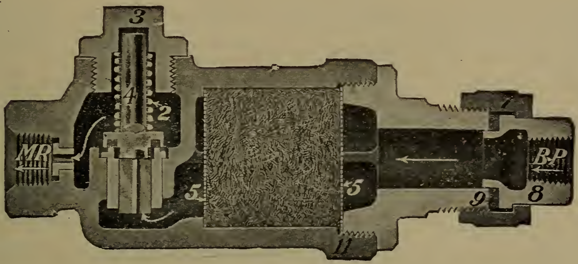


FIG. 52.—Combined Air Strainer and Check Valve.

At all other times the valve is cut out by means of a cut out cock placed in the pipe between the connection to the brake pipe and the combined strainer and check valve. When it is desired to use this feature, the double heading cock should be closed and both the automatic and independent brake valve handles placed in running position, then open the cut out cock in the dead engine feature pipe. Air will then flow from the brake pipe to the main reservoir through the combined strainer and check valve as shown in Fig. 52. On account of the tension of check valve spring 2, the pressure obtained in the main reservoir will be somewhat lower than the brake pipe pressure. The strainer protects the check valve and choke fittings from dirt; while the choke fitting prevents any sudden drop of brake pipe pressure, thus preventing the setting of the brakes when cutting in an uncharged reservoir.

THE DISTRIBUTING VALVE AND DOUBLE CHAMBER RESERVOIR

580. The distributing valve consists of two portions.

581. It is connected to a double-chamber reservoir; of these chambers the larger one is the pressure chamber, the smaller one the application chamber. The relative size of the two reservoirs is shown in Fig. 53.

582. The application chamber is ordinarily connected to the application portion of the distributing valve for the purpose of enlarging the volume in the application cylinder.

583. The equalizing portion and pressure chamber are used in automatic application only.

584. Reduction of brake pipe pressure causes the equalizing valve to connect the pressure chamber to the application chamber and cylinder, allowing air to flow from the former to the latter.

585. The upper slide valve connected to the piston rod of the application portion, admits air to the brake cylinders and is called the application valve. The lower one releases the air from the brake cylinders and is called the exhaust valve.

586. The air which is admitted to the brake cylinders by the application valve comes directly from the main reservoirs.

587. The pipe connections to the distributing valve are

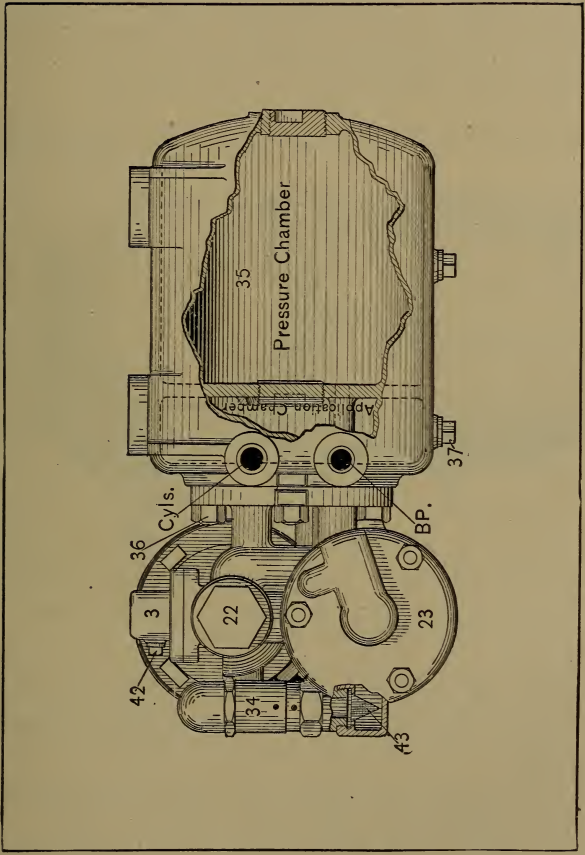


FIG. 53.—Distributing Valve and Double Chamber Reservoir.

illustrated in Fig. 54. There are three pipes connected to the left side and two to the right side of the double-chamber reservoir. The pipe connections are made to the reservoir body direct, to avoid disturbing the pipe joints when necessary to take the valve apart.

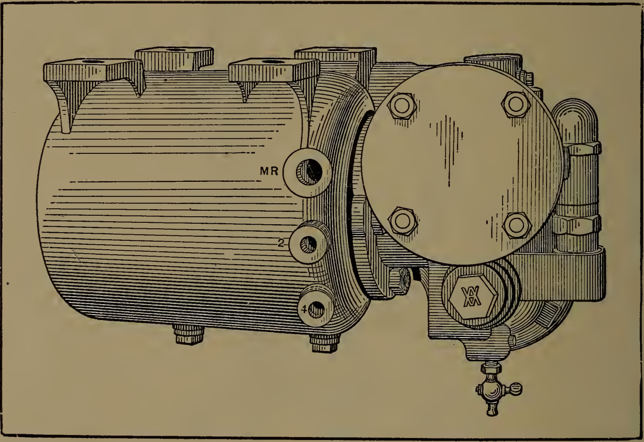


FIG. 54.—Distributing Valve Pipe Connections.

588. The connection marked *M R* leads from the main reservoir and supplies air to the application portion of the valve.

589. The middle one (marked 2) connects with the application chamber and application cylinder. This pipe will allow air to pass in or out between the chamber and the independent brake valve in an independent application or release and allow air to pass in from the

automatic brake valve when its rotary is in emergency position.

590. The lower left-hand pipe 4 is the distributing valve release pipe. It leads first to the independent brake valve with its rotary in running position; air can then pass to the automatic rotary valve, which must also be in running position to allow air from the application chamber and cylinder to escape.

591. Of the two on the right the upper one (marked *cyls*) is the brake cylinder pipe and branches to all brake cylinders on the engine and tender.

592. The lower connection (marked *B P*) is the brake pipe branch connections and is used in making automatic applications only.

593. While referring to the parts of this apparatus, the following names and numbers will be used: 2, Body; 3, Application valve; 4, Cover screw; 5, Application valve; 6, Application valve spring; 7, Application cylinder cover; 8, Cylinder cover, bolt, and nut; 9, Cylinder cover gasket; 10, Application piston; 11, Piston follower; 12, Packing leather expander; 13, Packing leather; 14, Application piston nut; 15, Application piston packing ring; 16, Exhaust valve; 17, Exhaust valve spring; 18, Application valve pin; 19, Application piston graduating stem; 21, Graduating stem nut; 22, Upper cap nut; 23, Equalizing cylinder cap; 24, Cylinder cap bolt and nut; 25, Cylinder cap gasket; 26, Equalizing piston; 27, Equalizing piston ring; 28, Graduating valve; 29, Graduating valve spring; 31, Equalizing valve; 32, Equalizing valve spring; 33, Lower cap nut; 34, Safety valve; 35,

Double chamber reservoir; 36, Reservoir stud and nut; 37, Reservoir drain plug; 38, Distributing valve drain cock; 39, Application valve cover gasket; 40, Application piston cotter; 41, Distributing valve gasket (located where distributing valve bolts to reservoir not shown); 42, Oil plug; 43, Safety valve air strainer; 44, Equalizing piston graduating sleeve; 45, Equalizing piston graduating spring nut; 46, Equalizing piston graduating spring.

Port *h* leads to the Application Cylinder, Automatic Brake Valve and Independent Brake Valve; *w*, to the Application Chamber; *i*, to the Distributing Valve Release Pipe; and *l*, to the Safety Valve.

Main reservoir pressure is always present in the chamber surrounding application valve 5, by its connection through passage *aa*, to the main reservoir pipe.

Chamber *b* to the right of application piston 10 is always in free communication with the brake cylinders, through passage *c* and brake cylinder pipe. Application cylinder *g* at the left of application piston 10 is connected by passage *h* with the equalizing valve seat and to the brake valves through the application cylinder pipe.

EXPLANATION OF DIAGRAMMATIC VIEWS OF THE DISTRIBUTING VALVE

To simplify the tracing of the ports and connections the various positions of this valve are shown in diagrammatic views, that is, the valve is distorted to show the parts differently than actually constructed, with the object of

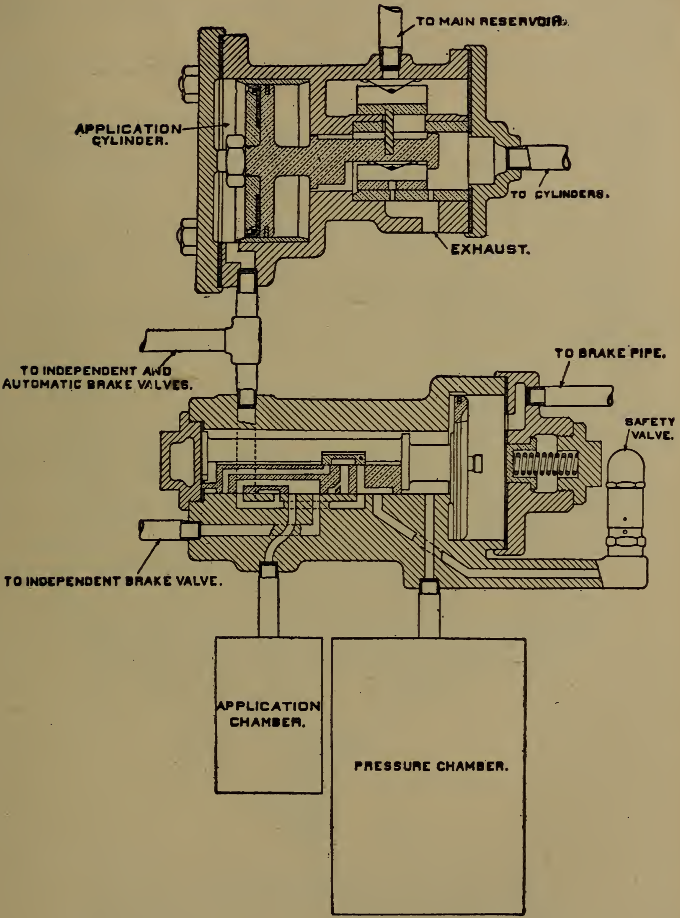


FIG. 55.—Diagrammatic View of the Distributing Valve and Double Chamber Reservoir.

explaining the operation clearly, instead of showing exactly how they are designed.

The chambers of the reservoir are for convenience in-

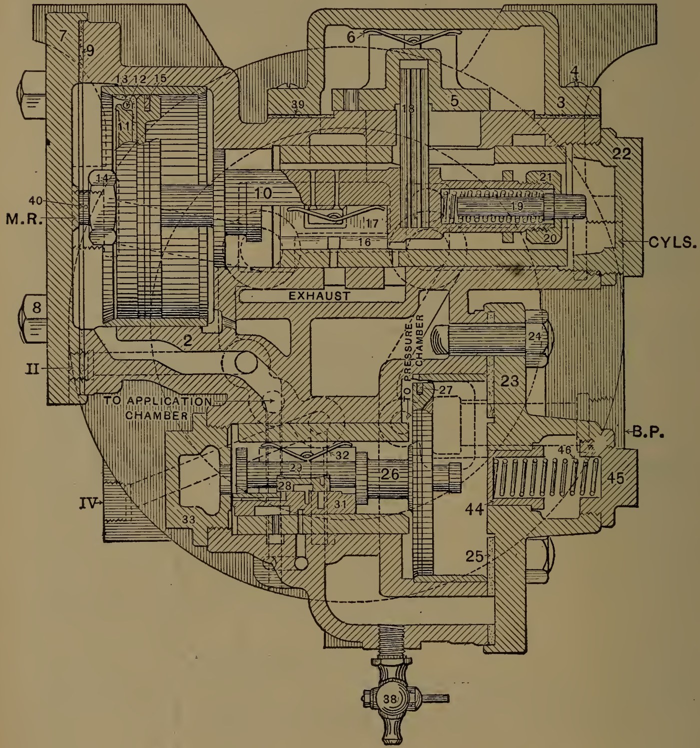
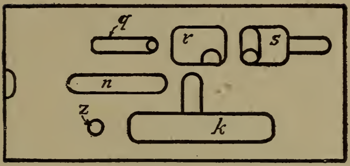


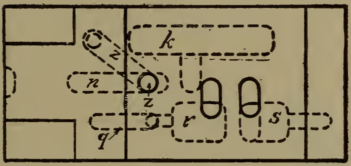
FIG. 56.—No. 6 Distributing Valve.

dicated at the bottom, as a part of the valve itself. Fig. 55 shows the valve separated into two parts, with the pipe connections made directly to the valves.

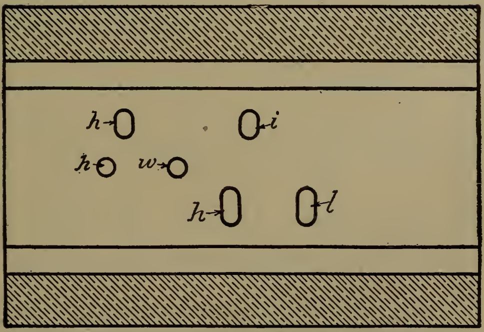
PLAN OF
GRADUATING VALVE.



FACE OF SLIDE VALVE.



PLAN OF SLIDE VALVE.



PLAN OF SLIDE VALVE SEAT.

FIG. 57.—Graduating Valve, Equalizing Valve, and Equalizing Valve Seat of the No. 6 Distributing Valve.

The upper part is the application portion and controls the admission of reservoir air to the brake cylinders, to apply the brakes or permit brake cylinder air to exhaust, to release the brakes.

The application portion of this valve is connected to the brake valves as well as to the equalizing portion, so that the valve may be operated with air either from a brake valve or the pressure chamber and thus operate the application piston applying or releasing the brakes.

The equalizing portion and its reservoir may be compared with that of a miniature brake set, the equalizing portion representing a triple valve, the pressure chamber the auxiliary reservoir; and the application chamber and its cylinder having the same pressure in it during an application as the brake cylinder.

DISTRIBUTING VALVE, AUTOMATIC OPERATION OF CHARGING POSITION

594. Brake pipe pressure flows into chamber *P* through *B P*, thence through feed groove *V* over the top of piston 26 into the chamber above equalizing valve 31 and through port *O*, to the pressure chamber, until the pressure on both sides of the piston 26 is equal.

DISTRIBUTING VALVE, AUTOMATIC SERVICE

595. When a service application is made with the auto, matic brake valve the brake pipe pressure in chamber *P* is reduced, causing a difference in pressure on the two

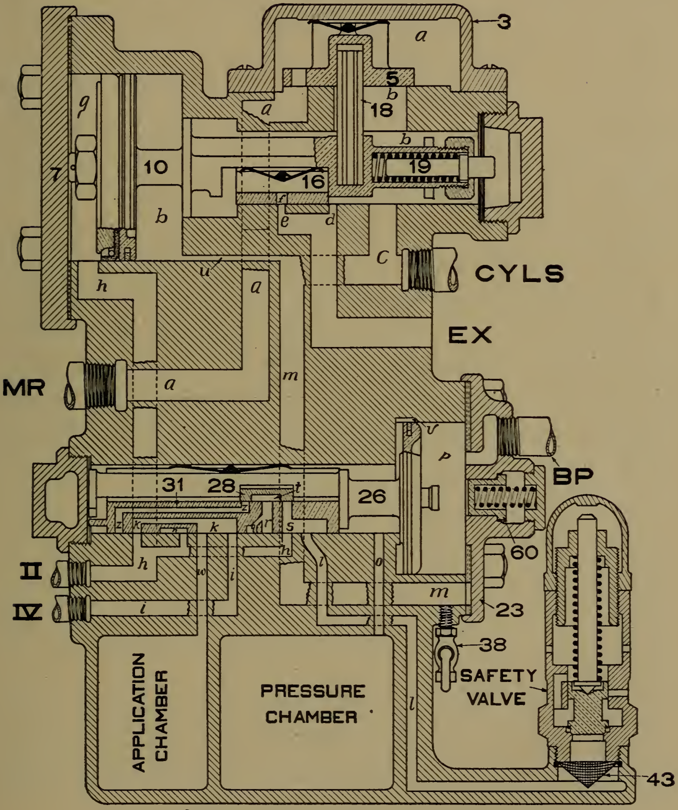


Fig. 58.—Release Automatic or Independent.

sides of piston 26, which results in the piston moving toward the right as shown in Fig. 59. The first movement of the piston to the right closes the feed groove and at the same time moves the graduating valve until it uncovers the upper end of port *Y*, in the equalizing valve 31.

As the piston continues its movement to the right the shoulder on the end of its stem engages the equalizing valve which is then also moved to the right, until the piston strikes equalizing piston graduating sleeve 44. Graduating spring 46 prevents further movement.

Port *Y* in the equalizing valve then registers with port *H* in the seat and cavity *N* in the equalizing valve connects port *H* and *W* in the seat. As the equalizing valve chamber is always in communication with the pressure chamber, air can now flow from the latter to both the application cylinder and application chamber. This pressure forces application piston 10 to the right as shown in Fig. 8, causing exhaust valve 16 to close exhaust ports *e* and *d* and to compress application piston graduating spring 20, also causing application valve 5 (by its connection with the piston stem through pin 18) to open its ports and allow air from the main reservoir to flow into chamber *b*, *b*, and through passage *c* to the brake cylinders.

During the movement just described cavity *t* in the graduating valve connects ports *r* and *s* in the equalizing valve and by the same movement ports *r* and *s* are brought to register with ports *h* and *l*, in the seat.

This establishes communication between the application cylinder and the safety valve, which being set at 68 pounds (three pounds above the maximum obtained in an emer-

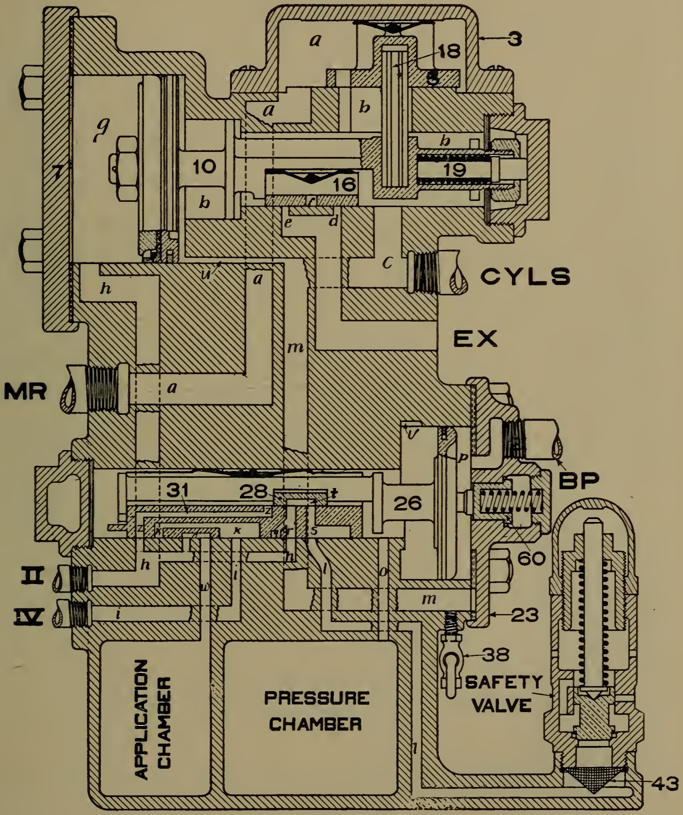


Fig. 59.—Automatic Service.

gency application from 70 pounds, brake pipe pressure) limits the brake cylinder pressure to this amount.

DISTRIBUTING VALVE, SERVICE LAP

596. When only a partial automatic service reduction of brake pipe pressure has been made, the positions described for automatic service continue until the pressure in the pressure chamber has been reduced a little below that remaining in the brake pipe, when the brake pipe exhaust has stopped at the brake valve.

As the pressure in the pressure chamber is reduced slightly below that remaining in the brake pipe, piston 26 will be moved to the left, moving graduating valve 28 with it until stopped by the shoulder on piston stem 26 striking the right-hand end of equalizing valve 31. This position is shown in Fig. 60.

In service lap position port *z* is closed by graduating valve 28, stopping the flow of air from the pressure chamber to the application cylinder and chamber. At the same time graduating valve 28 has also closed port *s*, stopping the flow of air to the safety valve, so that any possible leakage in the latter will not reduce the application cylinder pressure, which would cause a similar reduction in the brake cylinders.

When equalizing piston 26 and graduating valve 28 have moved to service lap graduating valve 28 stops the flow of air from the pressure chamber to the application piston cylinder *g*, and application chamber.

The pressure in cylinder *g*, and the application chamber,

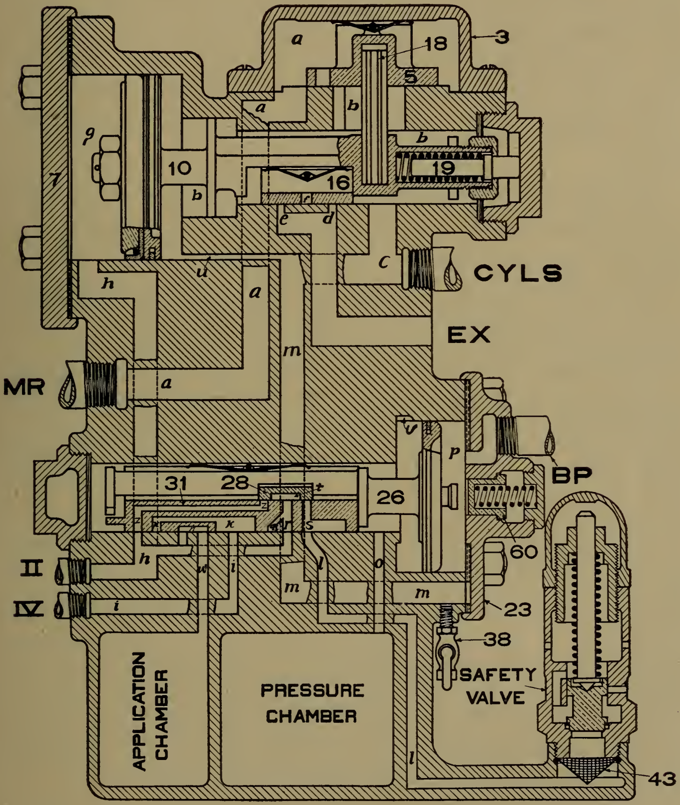


FIG. 60.—Service Lap.

holds application piston 10 to the right, until the flow of air past application valve 5 builds up a pressure in the brake cylinders and against the right side of piston 10, chamber *b*, equal to or slightly exceeding that in chamber *g*. The pressure thus being about equal on both sides of piston 10, the application piston graduating spring 20 moves piston 10 and application valve 5 to the left, closing port *b*.

Exhaust valve 16 does not move while piston 10 and application valve 5 are moving to service lap and brake cylinder exhaust ports *e* and *d* are closed.

The brake cylinder pressure is now practically the same as that in the application cylinder and chamber.

Application piston 10 now has application cylinder pressure on the left-hand side *g* and brake cylinder pressure on the right-hand side *b*. When either of these pressures become increased or decreased the piston will move toward the lower pressure.

If the brake cylinder pressure in *b* is reduced by leakage, the pressure in application cylinder *g* and the application chamber will force piston 10 to the right, opening application valve 5, permitting main reservoir air to flow to the brake cylinders to supply the leakage and build up the pressure in chamber *b*, until it is again slightly above that in application cylinder *g*, when graduating stem 19 and spring 20 moves the piston back to lap position.

In this way the brake cylinder pressure is always maintained equal with that in the application cylinder. This is the pressure-maintaining feature.

DISTRIBUTING VALVE, AUTOMATIC RELEASE

597. To release the distributing valve automatically, place the automatic brake valve in running position. This will open the exhaust port in the automatic rotary, permitting air from the application cylinder *g* and application chamber to exhaust to the atmosphere. At the same time feed valve pressure is flowing through the brake valve to the brake pipe, increasing the brake pipe pressure on the right side of equalizing piston 26, moving it to the left, carrying it with equalizing valve 31 and graduating valve 28 to full release position, as shown in Fig. 58.

The running position release should not be used when releasing train brakes.

To release the brakes when the engine is coupled to a train, place the automatic brake valve in full release position.

In this position the brake pipe is being recharged, releasing the train brakes and moving equalizing piston 26, equalizing valve 31, and graduating valve 28 to release position.

This action does not release the locomotive brakes, because it does not release the pressure from application cylinder *g* and application chamber.

With the automatic brake valve in full release position, the release pipe is closed by the rotary valve of the automatic brake valve and the application cylinder pipe is closed by the rotary valves of both brake valves.

To release the locomotive brakes, the automatic brake valve must be moved to running position. When in this position direct communication is established between application cylinder *g*, the application chamber, and the atmosphere, through the independent and automatic brake valves. As the pressure in application cylinder *g* is released, the pressure in the brake cylinder will force application piston 10 to the left, moving exhaust valve 16 with it, uncovering exhaust ports *d* and *e*, permitting brake cylinder pressure to escape to the atmosphere, and releasing the brakes.

To make a graduated release move the automatic brake valve from running to holding and from holding to running positions.

The amount of pressure exhausted from the brake cylinders will just equal the amount exhausted from the application cylinder and chamber.

DISTRIBUTING VALVE, EMERGENCY

598. The emergency position of the distributing valve is caused by a sudden and heavy reduction of brake pipe pressure. Such a reduction may be caused by placing the brake valve in the emergency position, by a hose bursting, or by train breaking in two.

The sudden reduction of brake pipe pressure in cylinder *p*, at the right of equalizing piston 26, permits the air stored in the pressure chamber to force piston 26 to the right with sufficient force when striking graduating sleeve 44 to compress its spring 46 and to seat against the leather gasket beneath the cylinder cap 23.

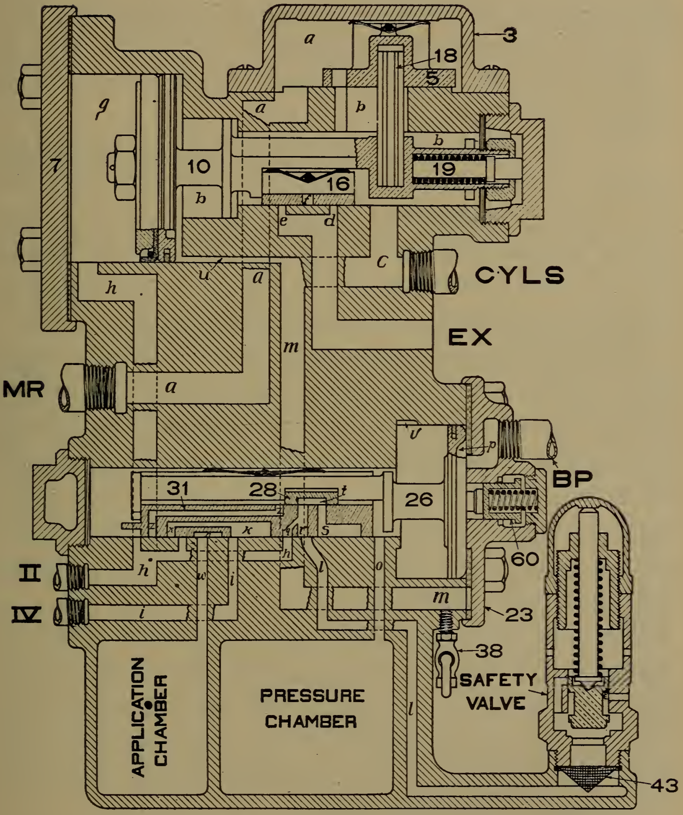


FIG. 61.—Emergency.

The movement of piston 26 and valve 31 is so quick, that valve 31 in passing over port *w* does not permit air from the pressure chamber to enter the application chamber; by the same movement port *h* is opened wide, making a direct opening from the pressure chamber to the application cylinder only.

The small volume of air necessary to fill the application cylinder causes a higher equalization than can be obtained by a service application. With a pressure of 70 pounds in the pressure chamber, it equalizes at about 65 pounds in the application cylinder, permitting a corresponding amount of pressure to enter the brake cylinders.

With the automatic brake valve in the emergency position, a small port in the rotary will permit main reservoir air to feed into the application cylinder pipe 11, increasing the pressure in the application cylinder until it equals the tension of the safety valve adjustment spring. The application cylinder and safety valve are now connected through port *h*, in the seat, cavity *q* and port *r* in the equalizing valve and port *i* in the seat.

The small port connecting cavity *q* and port *r* is of such a size that it permits air to escape from application cylinder to the safety valve at the same rate that air is supplied through the automatic brake valve. The pressure in the application cylinder is thus kept from raising above the adjustment of the safety valve.

In high-speed brake service with a brake pipe pressure of 110 pounds the pressure in the application cylinder and pressure chamber in emergency application will equalize at about 93 pounds. The maintaining port will also help to keep up the pressure, which will reduce slowly to about 75 pounds.

The pressure does not fall to 68 pounds, the pressure at which the safety valve is adjusted to open, because the inflow of air through the brake valve with a main reservoir of 130 to 140 pounds is equal at 75 pounds to the outflow through the small opening to the supply valve.

DISTRIBUTING VALVE, EMERGENCY LAP

599. The movable parts of the valve remain in the position shown in Fig. 61 until the brake cylinder pressure slightly exceeds the application cylinder pressure, when the application piston 10 and application valve 5 move back to the position known as emergency lap, as shown in Fig. 62.

600. To release the brakes after an emergency application the same movement of the brake valve is required as that following a service application, but the results are somewhat different. While the equalizing portion of the valve is in emergency position there is no pressure in the application chamber, so that when the equalizing portion piston 26, equalizing valve 31, and graduating valve 28 are moved to release position by the increased brake pipe pressure in cylinder *P*, the application cylinder and application chamber are connected by port *w*, cavity *k*, and port *h*. The pressure in the application cylinder expands into the application chamber until the pressure equalizes in the application chamber and cylinder; this reduction of

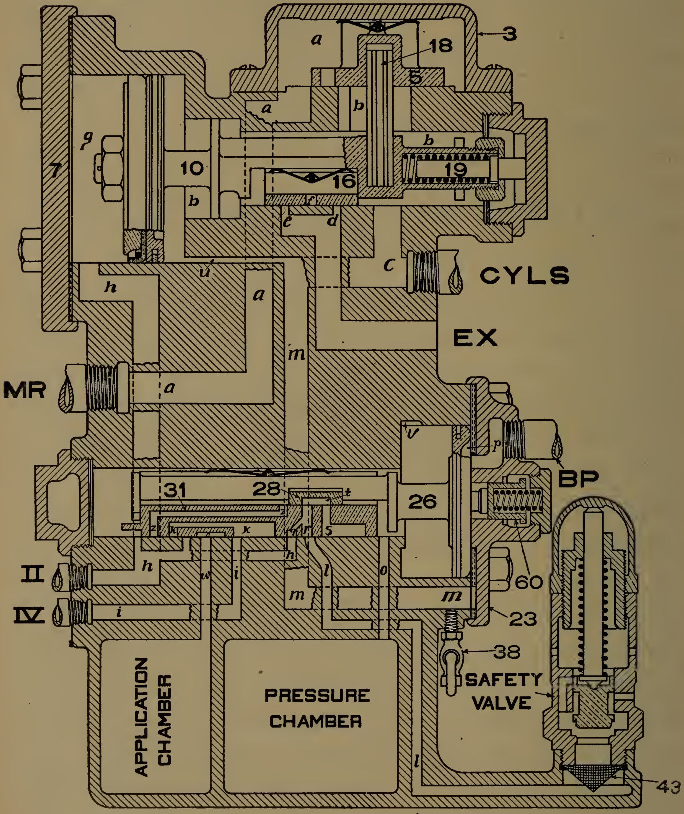


FIG. 62.—Emergency Lap.

pressure in the application cylinder causes the brake pressure to reduce automatically to about 15 pounds, which will be maintained until the automatic brake handle is placed in running position, opening the distributing valve exhaust port.

601. If the brakes are applied by a burst hose, train parting, or by the conductor's valve, the movement of equalizing valve 31 breaks the connection between port *h* and *i* through cavity *k*, closing the passage to the distributing valve release pipe. The brakes will apply and remain applied until the brake pipe pressure is restored. When the brakes are set in this manner, move the automatic brake valve to emergency position, to prevent the loss of main reservoir pressure which will be flowing to the brake pipe through the feed valve pipe and escaping to the atmosphere through the open brake pipe.

DISTRIBUTING VALVE, INDEPENDENT BRAKE, OPERATION OF

INDEPENDENT APPLICATION

602. When the brakes are applied or released with the independent brake valve, the equalizing portion of the distributing valve is not disturbed or moved in any way.

603. When the handle of the independent brake valve is moved to application position, main reservoir air (limited by the reducing valve to 45 pounds) flows to the application cylinder and chamber, forcing application piston 10 to the right as shown in Fig. 63. This movement

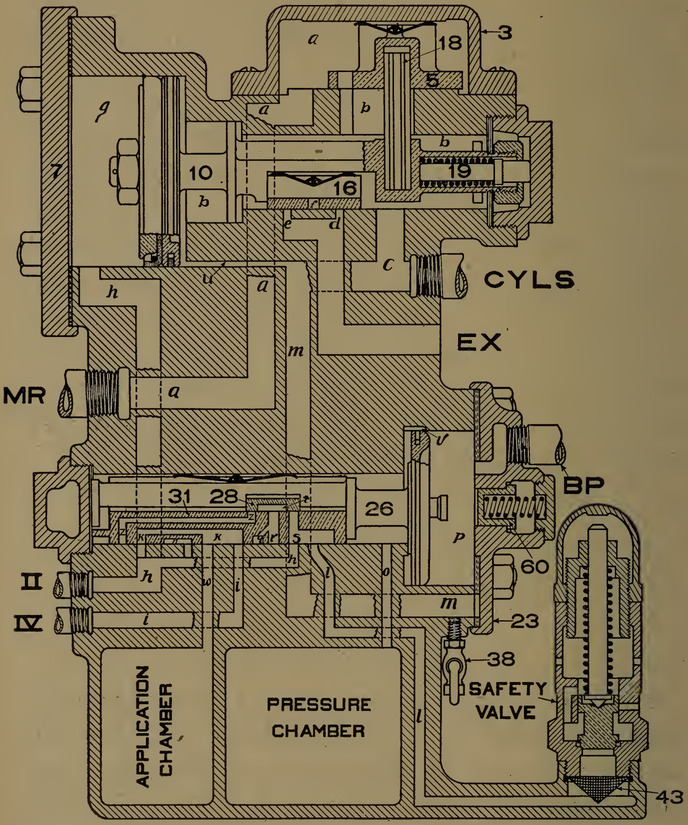


FIG. 63.—Independent Application.

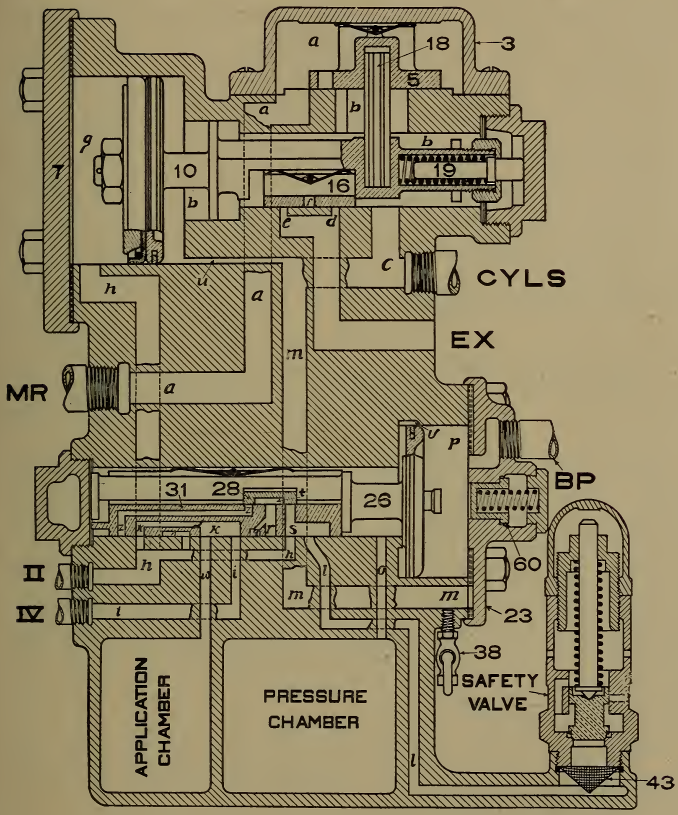


FIG. 64.—Independent Lap.

opens application valve 5, permitting main reservoir air to flow through to the brake cylinder; until the pressure in the brake cylinder slightly exceeds that in the application cylinder. Then the application piston graduating spring 20 will move the application piston 10 to the left, closing valve 5. The graduating spring has now expanded to its normal position and exerts no further power to move the piston. The pressures being equal on both sides of piston 10 it is prevented from moving any further by the resistance of exhaust valve 16. This position is illustrated in Fig. 64 and is called independent lap.

DISTRIBUTING VALVE, INDEPENDENT RELEASE

604. To release the brakes with the independent brake valve, move the handle to release position, opening a direct passage from the application cylinder to the atmosphere. As the pressure in application cylinder *g* becomes reduced, brake cylinder pressure in chamber *b* forces piston 10 to the left, moving exhaust valve 16, opening ports *e* and *d*, permitting brake cylinder pressure to escape to the atmosphere.

605. It is always possible to release the brakes on the engine and tender with the independent brake, even when automatically applied.

The position which the distributing valve will assume when automatically applied and independently released is shown in Fig. 65. This shows the application portion in full release, without changing the pressures in either

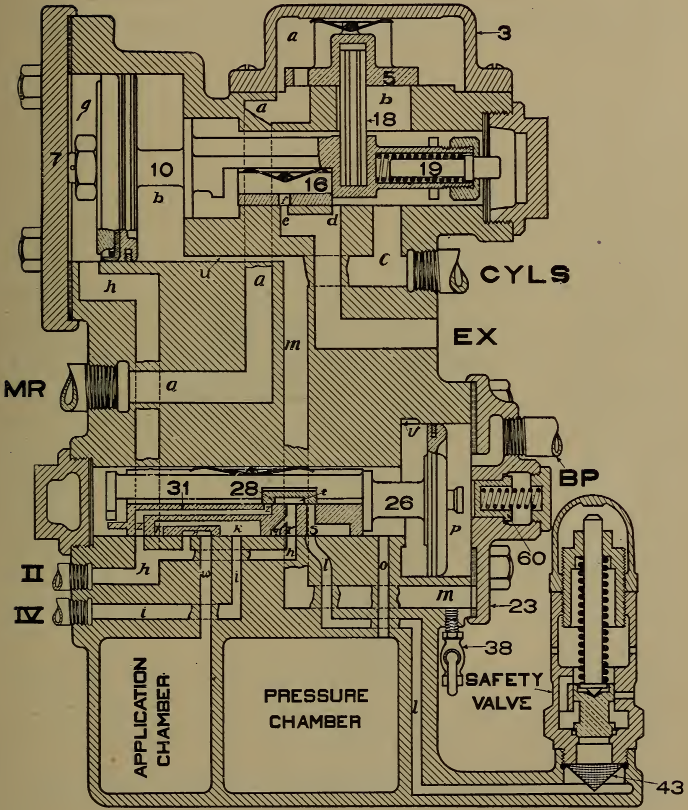


FIG. 65.—Release Position When Locomotive Brake is Released by Independent Brake Valve, After an Automatic Application.

the pressure chamber or brake pipe, or causing any movement of the equalizing portion.

606. To release the locomotive brakes independently after an emergency application of the automatic brake

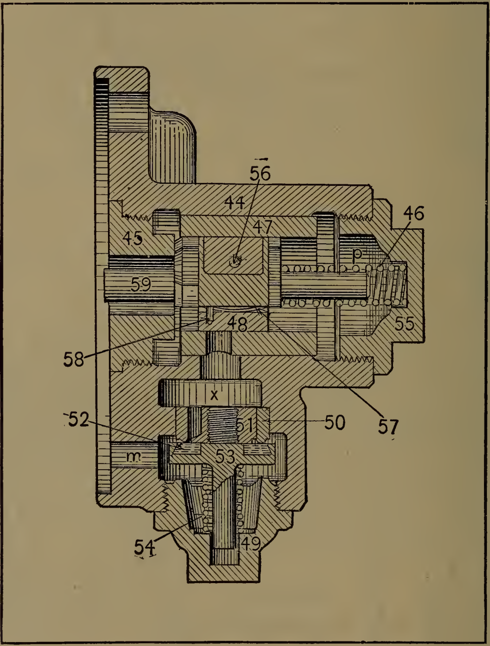


Fig. 66.—Quick Action Cylinder Cap for No. 6 Distributing Valve.

valve, it is necessary to hold the independent brake valve in full release position. This is occasioned by the maintaining feature which supplies air from the main reservoir to the application cylinder, through the automatic brake valve in emergency position.

DISTRIBUTING VALVE. QUICK ACTION CYLINDER CAP

607. There are certain conditions which occur in the operation of the locomotive brakes, when it is deemed advisable to have them operate in a manner similar to the quick action feature of the quick action triple valve; that is, vent brake-pipe pressure direct to the brake cylinders in an emergency application. This can be accomplished by removing cylinder cap 23, Fig. 56, and attaching the quick-action cylinder cap which is shown in Fig. 66.

608. The names of the parts and the numbers used to represent them are as follows:—47, cylinder cap; 48, emergency valve; 49, check valve, cap nut; 50, emergency valve graduating stem; 51, check valve guide; 52, rubber seat for check valve; 53, check valve; 54, check valve spring; 55, graduating spring; 56, cap nut; 57, emergency valve spring; 58, stop plug.

EMERGENCY POSITION OF DISTRIBUTING VALVE WITH QUICK ACTION CYLINDER CAP

609. In an emergency application of the brakes, piston 26 is forced quickly to the right, the extension on the piston engages the graduating valve stem 50, compressing the equalizing piston graduating spring 55. The movement of graduating valve stem 50 also moved emergency valve

48 to the right, opening port *j*. Brake pipe pressure now flows through port *j* to chamber *x* on top of check valve 53, forcing it down, then passing to the brake cylinders through passage *m* in the tap and distributing valve body. This vents brake pipe air direct to the locomotive brake cylinders.

610. When the brake cylinder and brake pipe pressures equalize, emergency valve 53 is forced to its seat by the tension of spring 54, thus preventing brake cylinder pressure from flowing back to the brake pipe.

When the brakes are released and piston 26 moves back to its normal position, the tension of spring 55 moves emergency valve graduating stem to the left, moving the emergency valve 48 with it, covering port *j* as shown in Fig. 66.

611. Any moisture gathering in chamber *b* is drained to the lower part of the distributing valve through port *u* to port *m*, where it may be drawn off through drain cock 38.

612. When it is desired to remove piston 10 or slide valve 16, it is absolutely necessary to first remove cover 3, application valve 5, and application valve pin 18, in the order mentioned.

THE H-6 ENGINEER'S BRAKE VALVE

613. The H-6 engineer's brake valve which is used in connection with the distributing valve as a part of the E T locomotive brake equipment, is somewhat different in construction from other styles of engineer's brake valves.

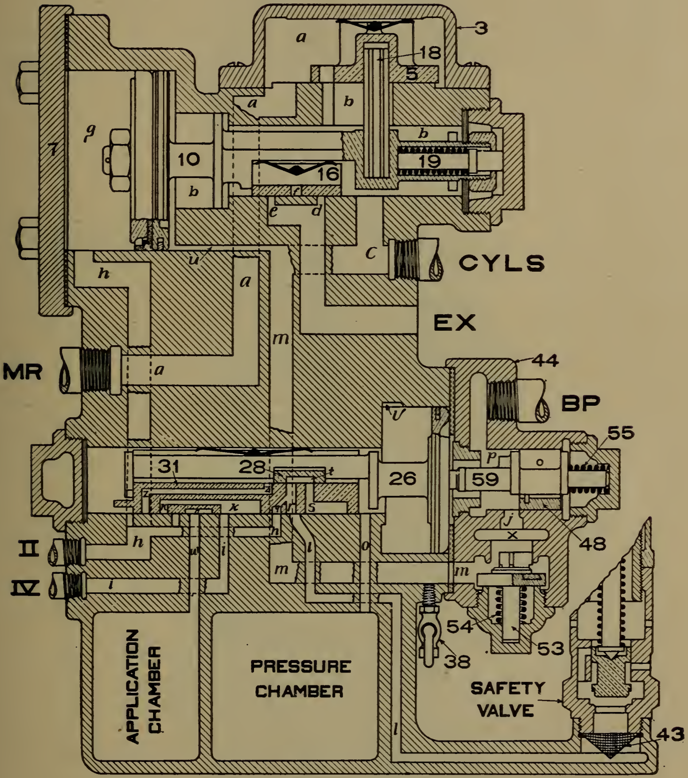


FIG. 67.—Emergency Position of Distributing Valve with Quick Action Cap.

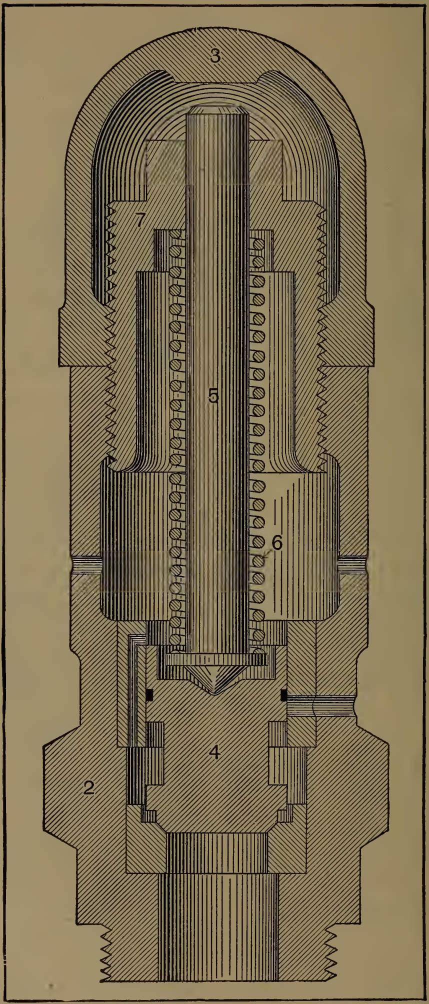


Fig. 68.—E-6 Safety Valve.

614. This is necessary in order to secure a perfect operation of the distributing valve.

615. This brake valve has six positions. They are, beginning at the left, 1st, release; 2nd, running; 3rd, holding; 4th, lap; 5th, service; 6th, emergency.

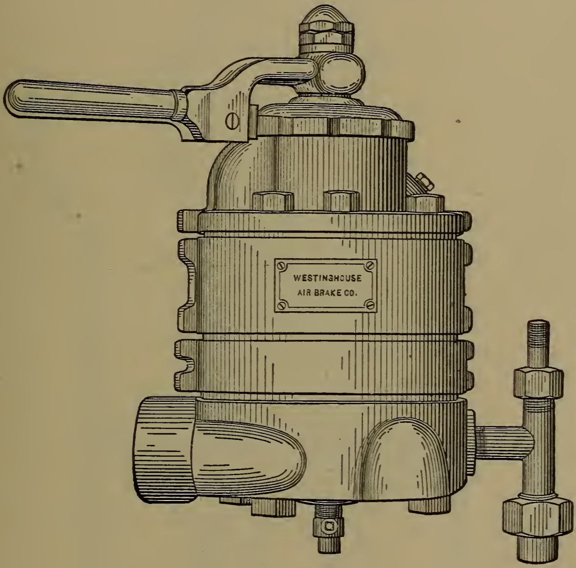


FIG. 69.—H-6 Automatic Brake Valve.

616. The names and numbers of the parts of this brake valve are as follows:—2, bottom case; 3, rotary valve seat; 4, top case; 5, pipe bracket; 6, rotary valve; 7, rotary valve key; 8, key washer; 9, handle; 10, handle latch–

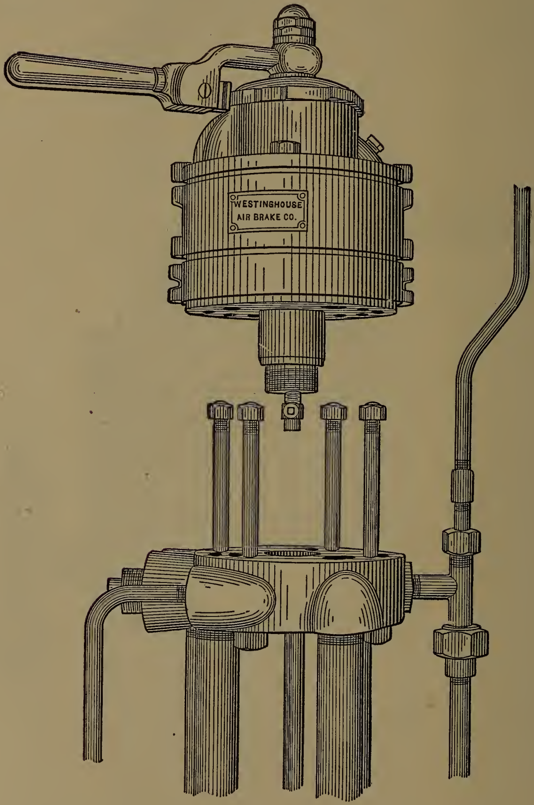


FIG. 70.—H-6 Automatic Brake Valve Removed from its Pipe Bracket.

spring; 11, handle latch; 12, handle latch screw; 13, handle nut; 14, handle lock nut; 15, equalizing piston; 16, equalizing piston packing ring; 17, valve seat upper gasket; 18, valve seat lower gasket; 19, pipe bracket gasket; 20, small union nut; 21, brake valve tee; 22,

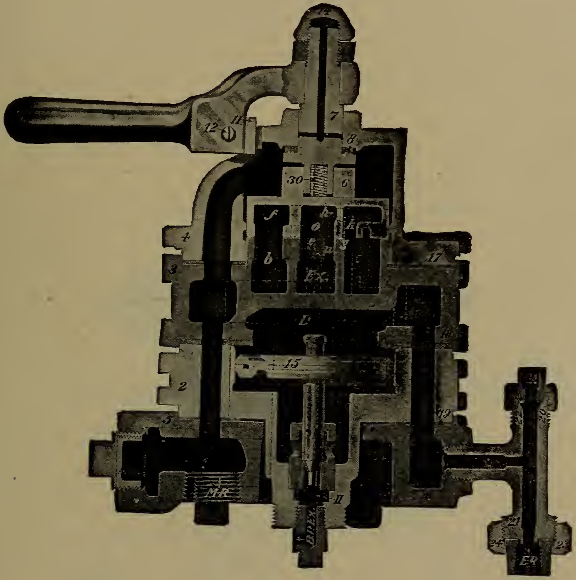


FIG. 71.—H-6 Automatic Brake Valve, Sectional View, No. 1.

small union swivel; 23, large union nut; 24, large union swivel; 25, bracket stud; 26, bracket stud nut; 27, bolt and nut; 28, cap screw; 29, oil plug; 30, rotary valve spring; 31, service exhaust fitting.

ROTARY VALVE, H-6 AUTOMATIC BRAKE VALVE

617. The arrangement of the ports, passages, and cavities of the rotary valve are shown in Fig. 71A.

Ports *a*, *j*, and *s* lead directly through the valve; port *s*, connecting with a groove in the face of the valve; *f* and *k*

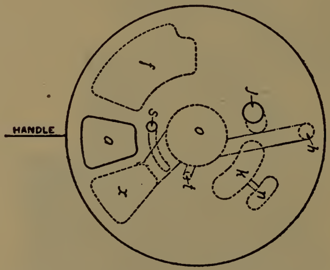


FIG. 71*a*.—Rotary Valve H-6 Automatic Brake Valve.

are cavities in the valve face; *o* is the exhaust cavity; *x* and *t* are ports in the face of the valve, connecting by cored passages with *o;* *h* is a port extending from the face of the valve over cavity *k* and connecting with exhaust cavity *o;* *n* is a small groove in the valve face which connects through a cavity in the valve with cavity *k*.

618. The arrangement of ports in the rotary valve seat are shown in Fig. 72, and are as follows:—*D* leads to the feed valve pipe; *B* and *C* lead to the brake pipe; *G* leads to chamber *D;* *E x* is the exhaust opening leading out at the back of the valve; *E* is the preliminary exhaust port leading to chamber *D;* *R* is the warning port leading to

the exhaust; *P* is the port leading to the pump governor; *l* leads to the distributing valve release pipe; *U* leads to the application cylinder pipe.

CHARGING AND RELEASE POSITION, H-6 TYPE

619. Air at main reservoir pressure passes through port *a* in the rotary valve to port *b* in the valve seat, thence to the brake pipe.

At the same time main reservoir pressure is flowing

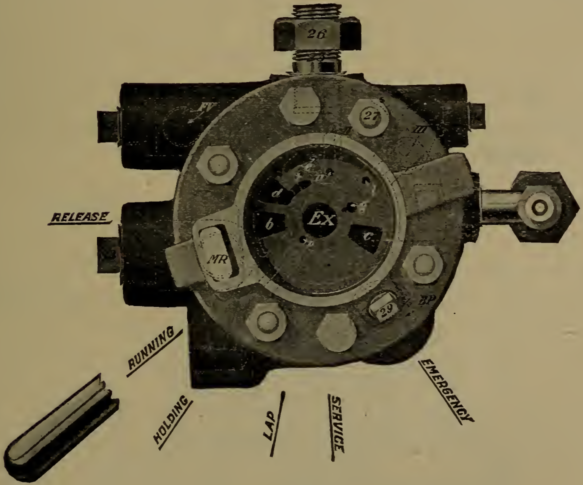


FIG. 72.—Rotary Valve Seat H-6 Automatic Brake Valve.

through port *j*, in the rotary valve and port *g* in the seat, on top of equalizing piston 15. Cavity *f* in the rotary valve now connects port *d* with warning port *r* in the seat,

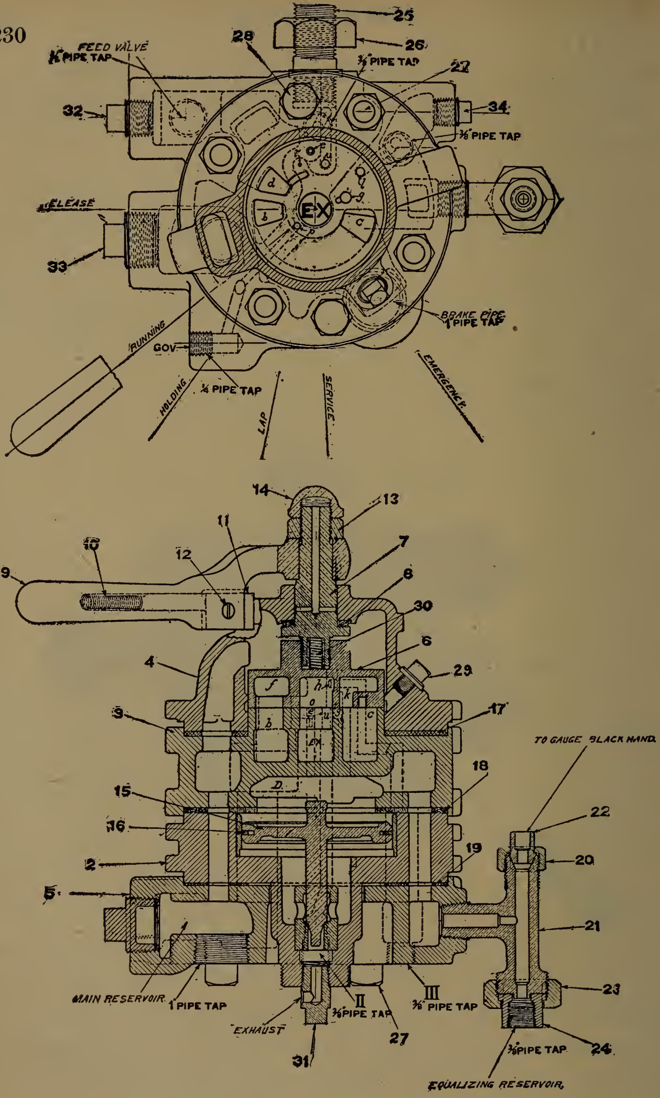


Fig. 73.—H-6 Automatic Brake Valve, Sectional View. No. 2.

allowing a small amount of air to escape into the exhaust cavity *ex*, causing a warning sound to notify the engineer that the brake valve handle is in release position.

620. If the brake valve handle is allowed to remain in full release position the brake pipe will become overcharged and equal the main reservoir pressure. To avoid this the handle must be moved to running or holding position, before the pressure in the brake pipe exceeds that at which the feed valve is set to maintain.

621. Main reservoir pressure flows from port *s* in the rotary valve through a groove in its face, and port *p* in the rotary valve seat to the lower connection of the excess pressure head of the pump governor.

622. The release or charging position of the brake valve will not release the locomotive brakes if they are applied.

RUNNING POSITION, H–6 TYPE

623. This is the position in which the brake valve handle must be carried when the brake system is charged and ready for use and the brakes are not being operated and to release locomotive brakes when applied.

624. While in running position cavity *f* in the rotary valve is in communication with ports *b* and *d* in the valve seat, providing a large passage from the feed valve direct to the brake pipe, which will now charge up as fast as the feed valve will supply the air, but cannot attain a higher pressure than that for which the feed valve is adjusted.

Cavity *k* in the rotary valve now connects ports *c* and *g* in the valve seat, allowing air to flow into chamber *d* and the equalizing reservoir. In this way the pressure is kept equal on both sides of equalizing piston 15.

625. Port *s* in the rotary and port *p* in the valve seat permit air at main reservoir pressure (which is present at all times above the rotary valve) to flow to the lower connection of the excess pressure head of the pump governor.

626. Port *h* in the rotary valve is now in communication with port *l* in the valve seat, connecting the distributing valve release pipe with the exhaust port *ex*.

627. When the brake valve is in running position and uncharged cars are cut in, the governor will stop the pumps until the difference in the brake pipe and main reservoir pressures is less than the normal excess pressure carried. For this reason release position of the brake valve should be used until all brakes (except the locomotive) release and the brake pipe is nearly charged.

628. When coupling the locomotive to a train the brakes should be applied until the brake pipe coupling has been made and the air turned in. Then the brake valve handle should be placed in full release until the brake pipe is nearly charged, when it should be moved to running position as explained before.

SERVICE POSITION, H-6 TYPE

629. To make a service application of the brakes move the brake valve handle to service position, allowing it to remain there until the desired reduction of brake pipe pressure has been made, then move the brake valve handle

to lap position which will stop any further reduction of pressure in chamber *d* and will hold the brakes applied until it is desired to make a further reduction of brake pipe pressure, or to release the brakes.

630. In order to make a gradual reduction of brake pipe pressure it is necessary to have preliminary exhaust port *e* restricted to a certain size, so that the full volume of air which it allows to pass through will not be sufficiently great to cause an emergency application of the brakes.

631. When the brake valve handle is in service position, port *h* in the rotary valve registers with port *e* in the valve seat, allowing air to escape from chamber *d* and the equalizing reservoir to the atmosphere through cavities *o* in the rotary valve and *ex* in the valve seat, all other ports being now closed.

632. The reduction of pressure in chamber *d* and the equalizing reservoir allows the brake pipe pressure under the equalizing piston 15 to raise it, unseating its valve allowing brake pipe air to flow to the atmosphere through the brake pipe exhaust fitting, marked *b, p, ex.*

633. When a sufficient reduction is made in the pressure in chamber *d*, the brake valve handle must be placed on lap, stopping any further reduction in that chamber.

634. Air will continue to flow from the brake pipe exhaust port until the brake pipe pressure has fallen a little below the pressure remaining in chamber *d*. The pressure in chamber *d* now being the greatest, it will force equalizing piston 15 down, gradually seating its valve and stopping the exhaust of brake pipe air.

635. It will be noticed that when a service application is

made with a long train line or brake pipe that the brake pipe exhaust is much longer than the preliminary or service exhaust. This is not on account of any greater reduction in pounds per square inch in the brake pipe, than was made in chamber *d*, but on account of the greater volume of air in the brake pipe than is contained in chamber *d* and the equalizing reservoir.

636. The amount of reduction in chamber *d* and the equalizing reservoir determines the reduction of brake pipe pressure, regardless of the length of the train.

LAP POSITION, H-6 TYPE

637. When the brake valve handle is on lap position all ports are blanked.

638. If placed in this position following a service application it holds the brakes applied until it is desired to make a further reduction of brake pipe pressure or to release the brakes.

HOLDING POSITION, H-6 TYPE

639. This is the most important feature of the H-6 brake valve in its connection with the operation of the distributing valve.

640. After having made an application of the brakes, the train brakes can be released and the brakes retained on the locomotive by placing the brake valve handle in holding position.

641. In this position the feed valve controls the brake

pipe pressure, permitting the brake pipe and auxiliaries on the train to recharge up to their normal pressure, while the brakes on the locomotive remain set, because in this position port *l* is closed.

642. The only difference between running and holding positions is that in holding position port *l* is closed, preventing the release of the distributing valve and locomotive brakes.

643. To release the distributing valve and locomotive brakes, move the brake valve handle from holding to running position, which opens port *l*, permitting the air from the application cylinder of the distributing valve to exhaust to the atmosphere, releasing the brakes.

644. The locomotive brakes may be graduated off by moving the brake valve handle from holding to running position and returning it to holding. In this way any amount of pressure desired can be released from the locomotive brake cylinders.

EMERGENCY POSITION, H–6 TYPE

645. To make an emergency application of the brakes move the brake valve handle quickly to emergency position. This position is used to make very sudden stops in case of danger or extreme emergency.

646. In this position port *x* in the rotary valve registers with port *c* in the valve seat, making a large and direct opening from the brake pipe to the atmosphere through cavity *o* in the rotary valve and *ex* in the valve seat.

647. The large volume of air taken suddenly from the

brake pipe causes the triple valves and distributing valve to move to emergency position and give maximum breaking power in the shortest possible time.

648. When the brake valve is in this position, main reservoir air will flow to the application cylinder through port *j*, which registers with a groove in the seat connecting with cavity *k*, thence through ports *n* in the valve and *u* in the seat to the application cylinder pipe, thereby maintaining application cylinder pressure. At the same time port *t* in the rotary valve registers with port *g* in the seat, allowing the air in the equalizing reservoir to flow to the atmosphere through cavity *o* and exhaust port *ex*, thus reducing the pressure in chamber *d* and the equalizing reservoir, during an emergency application of the brakes.

649. Oil plug 29 is for the purpose of oiling the rotary valve. The position of this plug is such that it is impossible to pour oil into the valve in excess of the amount needed. Valve oil should be used for this purpose.

THE S-6 INDEPENDENT BRAKE VALVE

650. The S-6 independent brake valve is used in connection with the H-6 automatic brake valve and the distributing valve, as a part of the E T No. 6 locomotive brake equipment.

651. The handle of this brake valve has five positions; which are, beginning at the first position on the left, 1st, release; 2nd, running; 3rd, lap; 4th, slow application; 5th, quick application.

652. The names and numbers of the parts of this valve

(as shown in the illustrations) are as follows:—2, Pipe Bracket; 3, Rotary Valve Seat; 4, Valve Body; 5, Return Spring Casing; 6, Return Spring; 7, Cover; 8, Casing Screw; 9, Rotary Valve; 10, Rotary Valve Key; 11, Rotary Valve Spring; 12, Key Washer; 13, Upper Clutch; 14, Handle Nut; 15, Handle; 16, Latch Spring; 17,

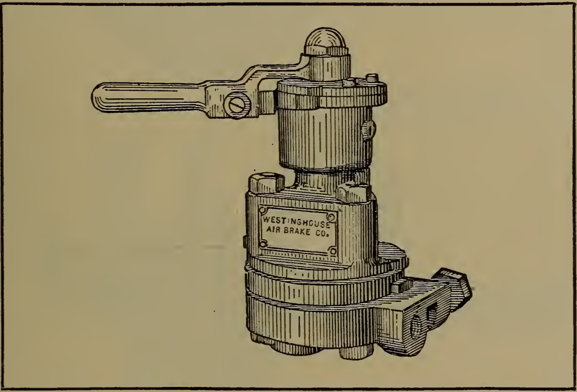


FIG. 74.—S-6 Independent Brake Valve Complete.

Latch Screw; 18, Latch; 19, Cover Screw; 20, Oil Plug; 21, Bolt and Nut; 22, Bracket Stud; 23, Bracket Stud Nut; 24, Upper Gasket; 25, Lower Gasket; 26, Lower Clutch; 27, Return Spring Stop; 28, Cap Screw.

653. The arrangement of ports in the rotary valve and seat are as follows:—Exhaust cavity *g* in the rotary valve is always in communication at one end with exhaust port *h;* groove *e* in the face of the valve communicates at one end with a port through the valve.

This groove is always in communication with a groove in the seat, connecting with supply port *b* and through the opening just mentioned air is admitted to the chamber above the rotary valve, holding it to its seat.

Port *m* is connected by a small hole with groove *e; f* is a groove in the face of the valve; *l* is the warning port

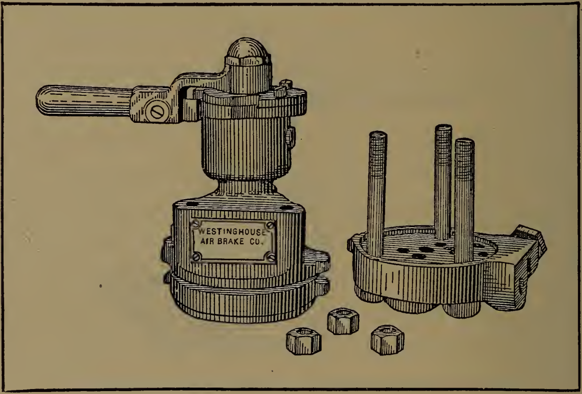


FIG. 75.—S-6 Independent Brake Valve Removed from Pipe Bracket.

which extends through the rotary valve and connects with port *k* in full release position.

Referring to the valve seat, port *b* leads to the reducing valve pipe; port *a* leads to that portion of the distributing valve pipe which connects to the distributing valve at *IV*. Port *c* leads to the other portion of the release pipe which connects to the automatic brake valve at *III*.

Port *d* leads to the application cylinder pipe which connects to the distributing valve at *II*. Port *h* in the

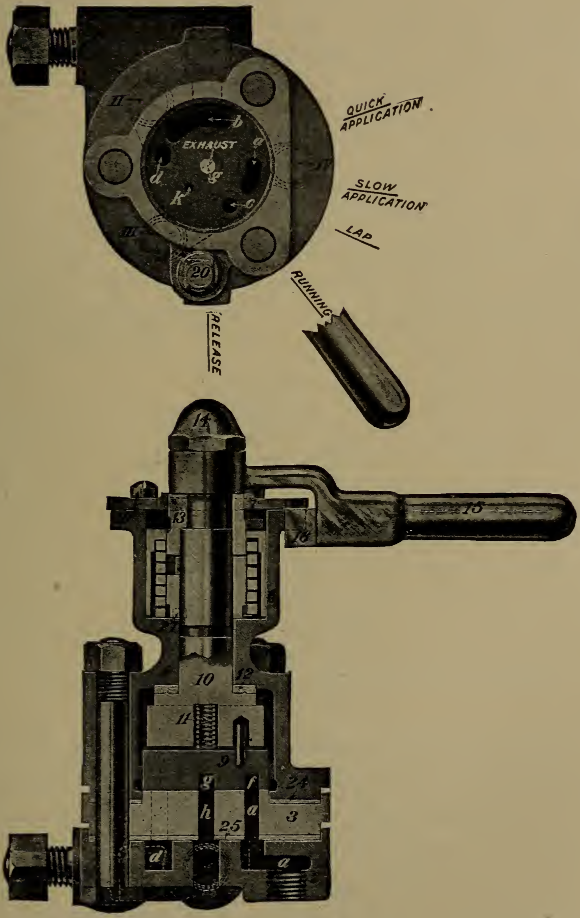


FIG. 76.—S-6 Independent Brake Valve, Sectional View.

center is the exhaust port leading down directly to the atmosphere.

Port *k* is the warning port leading to the atmosphere.

RUNNING POSITION, S-6 TYPE

654. The handle of the S-6 independent brake valve should be carried in running position at all times when not in use. In this position groove *f* in the rotary connects port *a* and *c* in the valve seat, thus establishing communica-

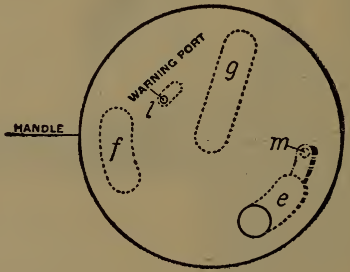


FIG. 76*a*.—Rotary Valve S-6 Independent Brake Valve.

tion through the distributing valve release pipe between the application cylinder of the distributing valve and port *l* of the automatic brake valve, so that the distributing valve can be released by the latter. With both the automatic and independent brake valves in running position, the application cylinder of the distributing valve is in direct communication with the atmosphere.

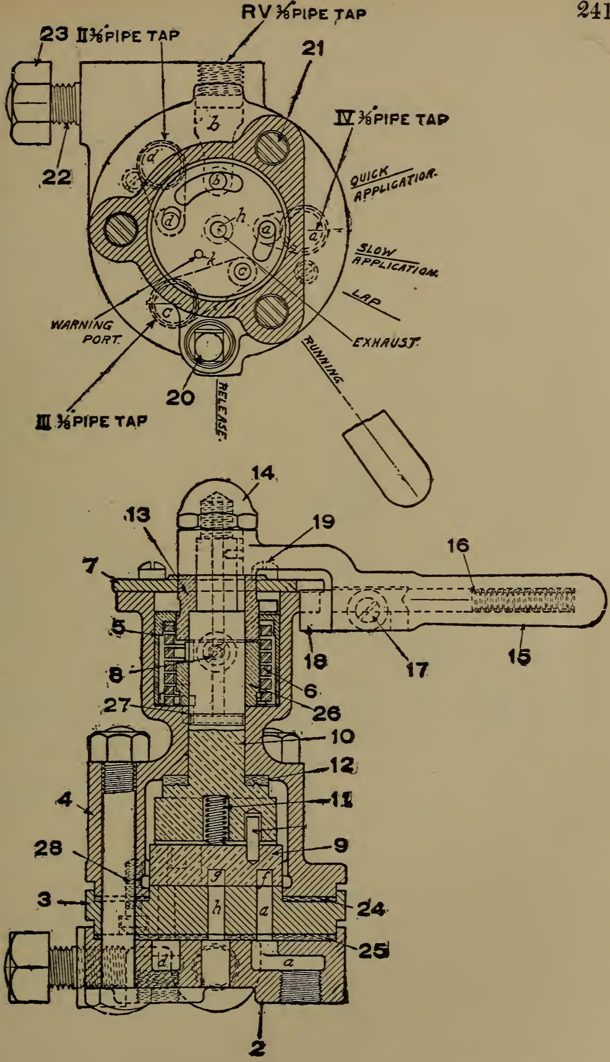


FIG. 77.—S-6 Independent Brake Valve, Reference Diagram.

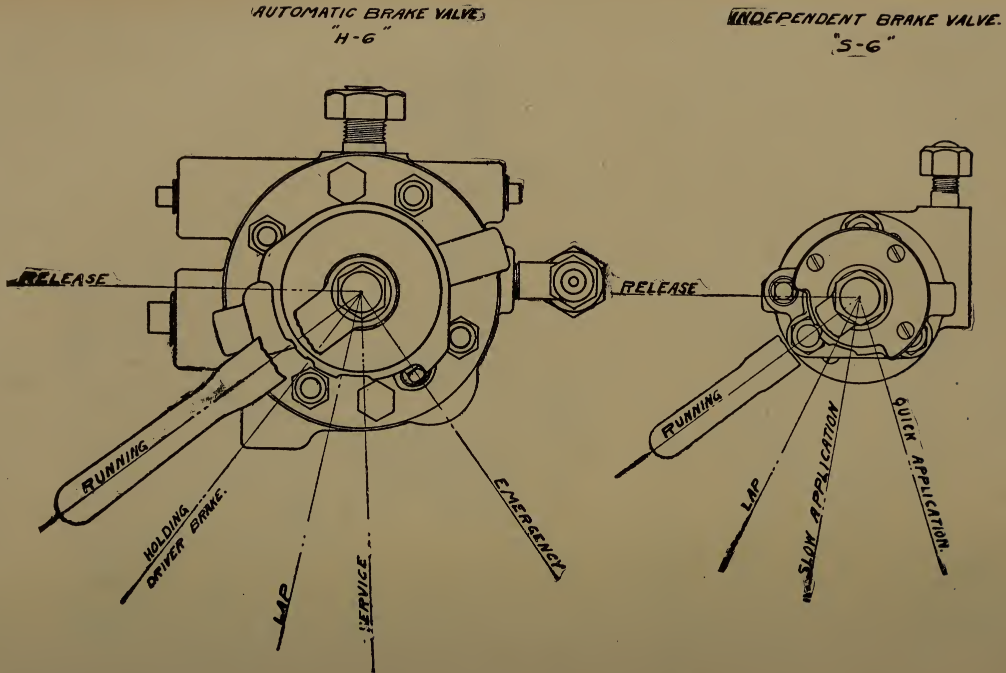


FIG. 78.—Position of Brake Valve Handles.

SLOW APPLICATION POSITION, S-6 TYPE

655. To apply the brakes gradually with the S-6 independent brake valve, move the handle to slow application position. Port *m* will now register with port *d*, allowing air to flow from the reducing-valve pipe through port and groove *b* in the seat, groove *e* in the rotary valve and the comparatively small port *m* to port *d*, thence through the application cylinder pipe to the application cylinder of the distributing valve.

QUICK APPLICATION POSITION, S-6 TYPE

656. To apply the brakes quickly move the handle of the brake valve to quick application position; when groove *e* will connect ports *b* and *d* directly; making a large and direct opening from the feed valve pipe to the application cylinder of the distributing valve, applying the brakes much quicker than when the slow application position is used.

LAP POSITION, S-6 TYPE

657. When the brake valve handle is moved to lap position after an application of the brakes, it will hold the independent brakes applied. The application piston and valve of the distributing valve supplying any reduction of pressure in the brake cylinders caused by leakage or otherwise has been explained.

RELEASE POSITION, S-6 TYPE

658. The release position of the S-6 independent brake valve is only necessary when it is desired to release the application cylinder pressure, to release the locomotive brakes when the automatic brake valve is not in running position.

659. Return spring 6 will automatically move the brake valve handle 15 from release to running or from quick to slow application position. This is to prevent leaving the handle in release position, which would prevent the setting of the locomotive brakes with the automatic brake valve. The spring also helps the engineer to locate the point between slow and quick application positions.

660. If the return spring becomes broken, allowing the brake valve to go to release position, the engineer would be warned by air escaping through port *l* in the rotary valve and warning port *k* in the seat.

661. Oil plug 20 is provided for the same purpose as that described with the automatic brake valve.

THE B-6 FEED VALVE

662. The B-6 feed valve is an improved form of slide-valve feed-valve. This valve charges quicker and regulates the brake pipe pressure more accurately than the old-style valves. It has a high and low brake pipe pressure control feature, which makes it very easy to change from low- to high-pressure braking power.

663. This valve is connected directly to main reservoir pressure and controls the feed-valve-pipe pressure at all times and the brake-pipe pressure when the handle of the automatic brake valve is in running or holding position. This valve is interchangeable with previous types.

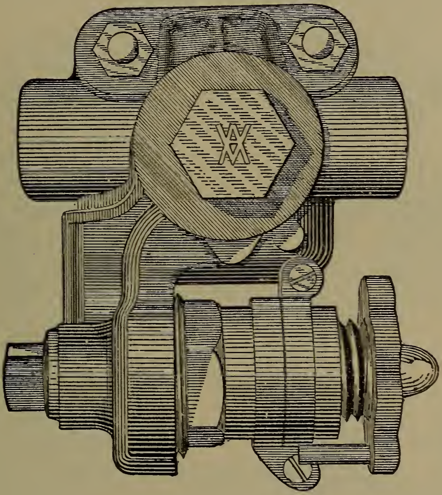


FIG. 79.—B-6 Feed Valve.

664. The names and numbers of the parts as shown in the illustrations are as follows:—2, Valve Body; 3, Pipe Bracket; 5, Cap Nut; 6, Piston Spring; 7, Piston Spring Tip; 8, Supply Valve Piston; 9, Supply Valve; 10, Supply Valve Spring; 11, Regulating Valve Cap; 12, Regulating Valve; 13, Regulating Valve Spring; 14, Diaphragm; 15, Diaphragm Ring; 16, Diaphragm Spindle; 17, Regu-

lating Spring; 18, Spring Box; 19, Upper Stop; 20, Lower Stop; 21, Stop Screw; 22, Regulating Hand Wheel.

665. The B-6 feed valve is constructed with a supply part and a regulating part. The supply part consists of the supply valve 9 and its spring 10, the supply valve piston 8

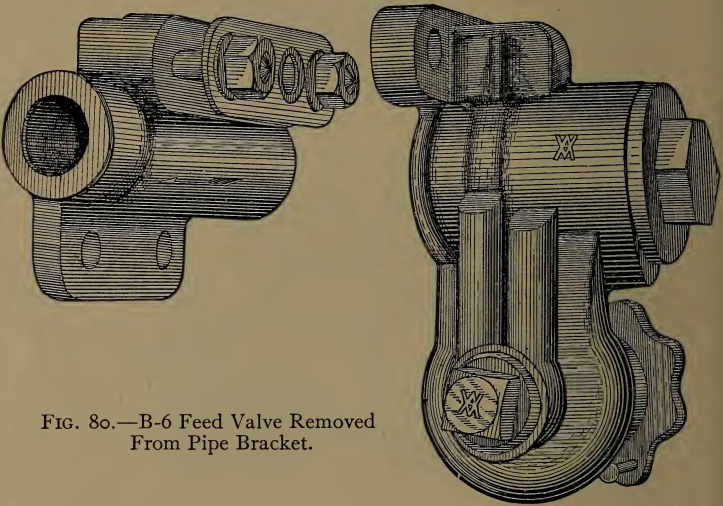


FIG. 80.—B-6 Feed Valve Removed From Pipe Bracket.

and its spring 6. The regulating part consists of the regulating valve 12, regulating valve spring 13, diaphragm 14, diaphragm spindle 16, regulating spring 17, and regulating hand wheel 22.

666. The operation of this valve is as follows:—

Main reservoir pressure enters the valve at *M R*, flowing through passage *a*, *a*, to supply valve chamber *b*, forcing piston 8 to the left, compressing spring 6, causing the port

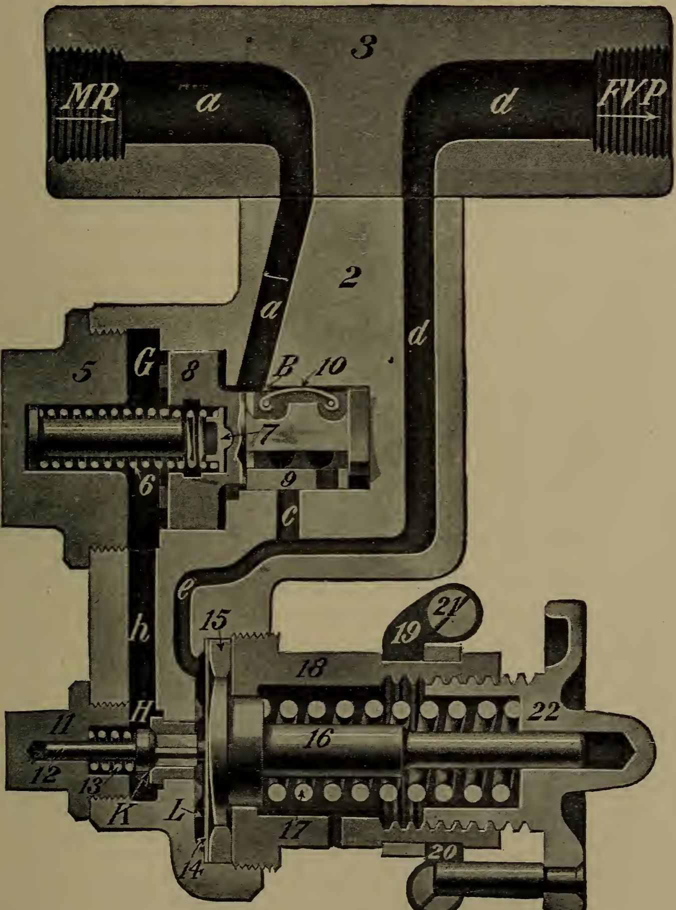


FIG. 81.—B-6 Feed Valve, Closed.

in slide valve 9 to register with port *e* in its seat. Air now flows directly from *a* through *b*, *c*, and *d* to the feed valve pipe marked *f*, *v*, *p*. At the same time air is flowing by piston 8 to chamber *g*, then through passage *h* and *h* past regulating valve 12, through port *k* to diaphragm chamber 1, thence through *e*, joining the pressure flowing through port *c* and passage *d* to the feed-valve pipe.

When the pressure in the feed-valve pipe, passage *d*, *e* and diaphragm chamber *l* exceeds the tension of adjustment spring 17, it will force diaphragm 14 to the right, compressing adjustment spring 17 and allowing regulating valve 12 to move to its seat, closing port *k*, stopping the flow of air through chamber *g*, causing the pressure to equalize on both sides of piston 8.

The tension of spring 6 which was compressed when supply piston 8 moved to the left, now forces piston 8 and slide valve 9 to the right, closing port *c* and stopping the flow of air from the main reservoir to the feed valve pipe. When the pressure in the feed valve pipe has become sufficiently reduced to relieve the pressure on diaphragm 14, adjusting spring 17 will force the diaphragm against the regulating valve stem 12, forcing it from its seat releasing the pressure in passage *h*, *h* and *G* and allowing it to flow to the feed-valve pipe.

The pressure on the left side of piston 8 now being less than that on the right side, the piston 8 and slide valve 9 will again move to the left, uncovering port *c*, allowing air to again flow to the feed valve pipe until its pressure equals the tension of adjustment spring 17, when piston 8 and slide valve 9 will again close port *c* as described.

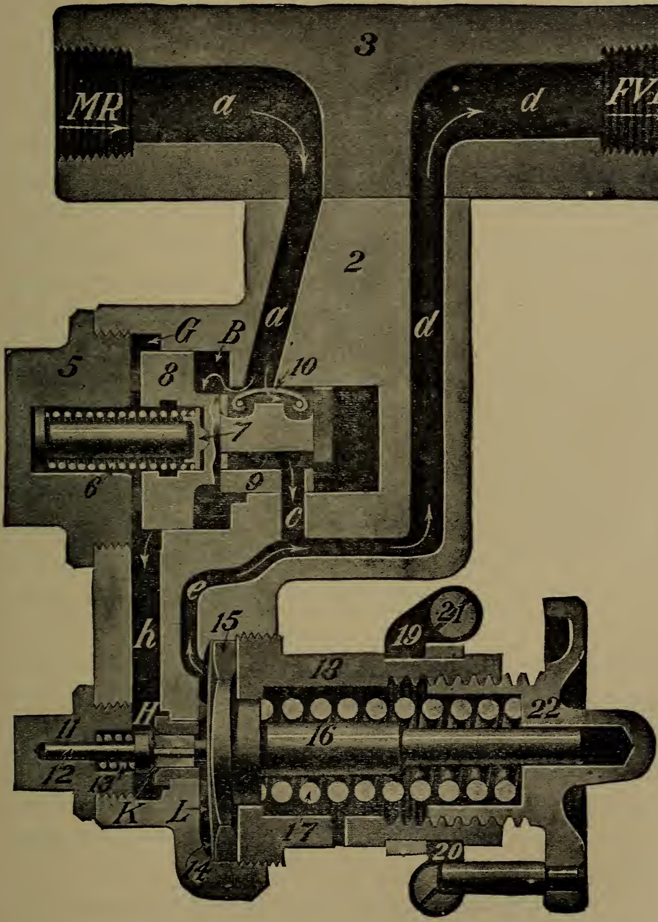


FIG. 82.—B-6 Feed Valve, Open.

667. The distinguishing feature of this valve is the arrangement for changing almost instantly from low to high-pressure service. This is accomplished by two rings placed on the adjustment spring box 18. These rings are split through the lugs and may be secured in any position, the lugs acting as stops for a pin which is placed in the adjusting handle 22. When these stops 19 and 20 are properly adjusted the feed pipe pressure can be changed from one brake pipe pressure to the other, simply by moving handle 22 until its pin strikes either one of the stops. When the pin rests against stop 19 it should give high-pressure service and when resting against stop 20 it should give low-pressure service.

668. As feed valve pressure is attached to the top of the excess pressure governor head any change in the feed valve pipe pressure will have a corresponding effect on the reservoir pressure.

DOUBLE-HEADING

669. When double-heading, the leading engine should if possible control the train brakes. When coupling two engines together for double-heading purposes, examine the couplings to see that they are properly made, that all valves and cut out cocks are in their proper position, then test the brakes by an application from the controlling engine.

670. When double-heading with an engine equipped with a G-6 brake valve, place the brake valve in running position and close the double heading cut out cock. The

brakes on the locomotive can now be operated the same as a car in the train.

671. When double-heading with the H-5 brake valve, place the automatic brake valve handle on lap position and close the double heading cut out cock under the automatic brake valve; place the independent brake valve handle in running position.

672. When double-heading with the H-6 brake valve, place both the automatic and independent brake valve handles in running position and close the double-heading cut out cock under the automatic brake valve.

673. The H-5 brake valve and the H-6 brake valve are very similar in appearance, but a close observer will be able to see the difference. To overcome any possibility of mistakes occurring through the similarity of the valves in appearance and the difference in the positions of the brake valve handles when double-heading, the H-6 valve is marked with a plate on the side. The H-5 valve is not marked.

TRIPLE VALVES

THE QUICK ACTION TRIPLE VALVE

674. Each triple valve has two sets of operative parts. One set being operated during service application of the brakes, the other or emergency part acting in conjunction with the service part in emergency position.

675. The service application parts are:—A piston, with slide valve and graduating valve attachment.

676. The emergency parts are:—An emergency piston, emergency valve, a check valve and graduating valve.

QUICK ACTION TRIPLE VALVE

CHARGING POSITION

677. Air from the brake pipe passes through a strainer placed in the pipe to the triple valve, thence through passage *e* and *g* into chamber *h*, to the left of the triple valve piston, then through the small feed port *i*, in the bushing

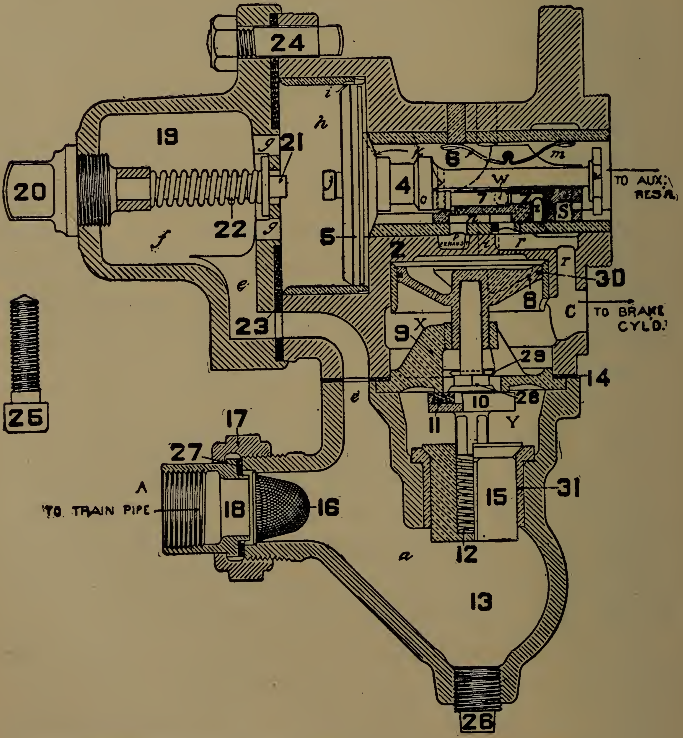


FIG. 83.—Quick Action Triple Valve, Release Position.

and *k*, in the piston seat, filling slide valve chamber *m*, thence to the auxiliary reservoir. The air continues to flow through the valve in this manner until the pressure has equalized on both sides of the triple valve piston. Brake pipe pressure now exists in the triple valve and auxiliary reservoir.

QUICK ACTION TRIPLE VALVE

SERVICE APPLICATION

678. When the automatic brake valve is placed in service position, brake pipe pressure is gradually reduced in chamber *h* to the left of the triple valve piston. The greater pressure now on the right of the piston forces it to the left, closing port *i*, cutting off communication between the brake pipe and the auxiliary reservoir.

The graduating valve now uncovers port *z* in the slide valve, which moves so that port *z* is in communication with port *r* (in the valve seat) which leads to the brake cylinder.

When the slide valve moves to the left, opening communication from the auxiliary reservoir to the brake cylinder, it also closes the exhaust port from the brake cylinder.

When a full service application has been made, the triple valve piston will be stopped from moving any farther to the left by graduating valve stem 21.

As soon as the flow of air from the auxiliary reservoir to the brake cylinder has reduced the pressure on the right side of the triple valve piston below that in the brake pipe, the piston will move back, reseating the graduating valve, stopping any further flow of air to the brake cylinder until another application is made.

679. When two or more reductions of pressure are made without releasing the brakes, the slide valve only moves on the first reduction, while the graduating valve uncovers port *z* on every application and closes it every time the brake valve is placed on lap.

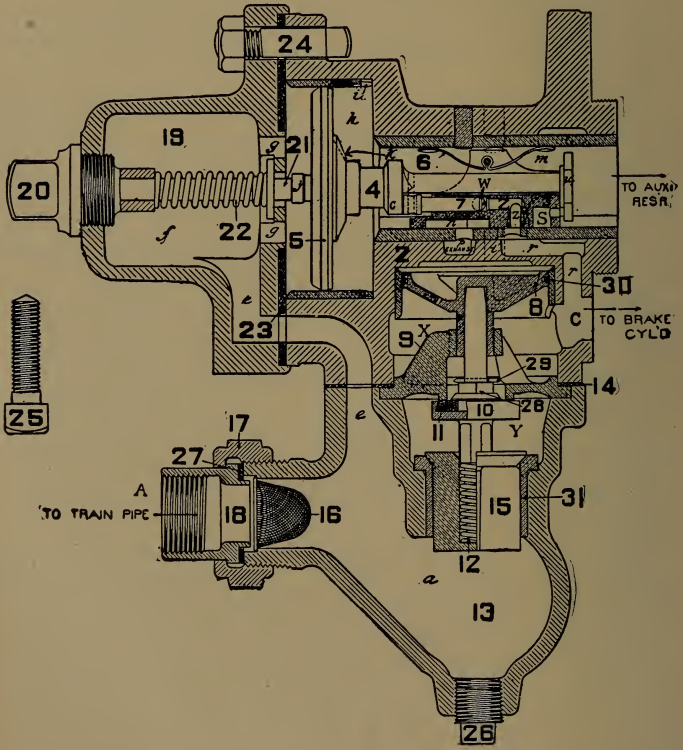


FIG. 84.—Quick Action Triple Valve, Service Application Position.

QUICK ACTION TRIPLE VALVE

LAP POSITION

680. Lap position is used for the purpose of holding the pressure in the brake cylinder after an application, until it is desired to make a further application or to release the brakes.

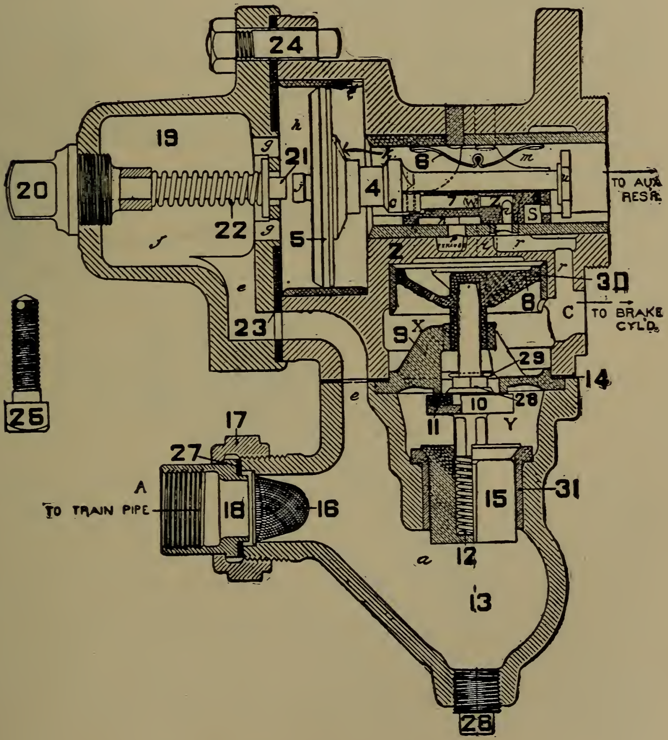


FIG. 85.—Quick Action Triple Valve, Lap Position.

Lap position also prevents brake pipe pressure from passing to the auxiliary reservoir.

QUICK ACTION TRIPLE VALVE

RELEASE POSITION

681. When the brake valve handle is placed in release position, the flow of air into the brake pipe increases the pressure on the left side of the triple piston above that remaining on the right side.

As the triple valve piston moves to the right it engages the slide valve, moving it to the right, bringing cavity *n* in communication with port *r*, and exhaust port *p*, allowing the pressure on the brake cylinder to exhaust to the atmosphere, and permits brake pipe pressure to flow through ports *i* and *k*, to the auxiliary, as described in charging position.

QUICK ACTION TRIPLE VALVE

EMERGENCY POSITION

682. When the brake valve handle is placed in emergency position; or when a large volume of air is suddenly exhausted from the brake pipe, as when a hose bursts; or when a train breaks in two; the sudden reduction of brake pipe pressure will cause the triple valve piston to move out so quickly that the graduating spring cannot withstand the impact of the extension on the triple valve piston, but springs back, allowing the piston to travel its full stroke.

683. The slide valve now uncovers port *t* in its seat,

admitting air from the slide valve chamber and auxiliary reservoir into chamber above the emergency piston, forcing it down and unseating the emergency valve 10. The air

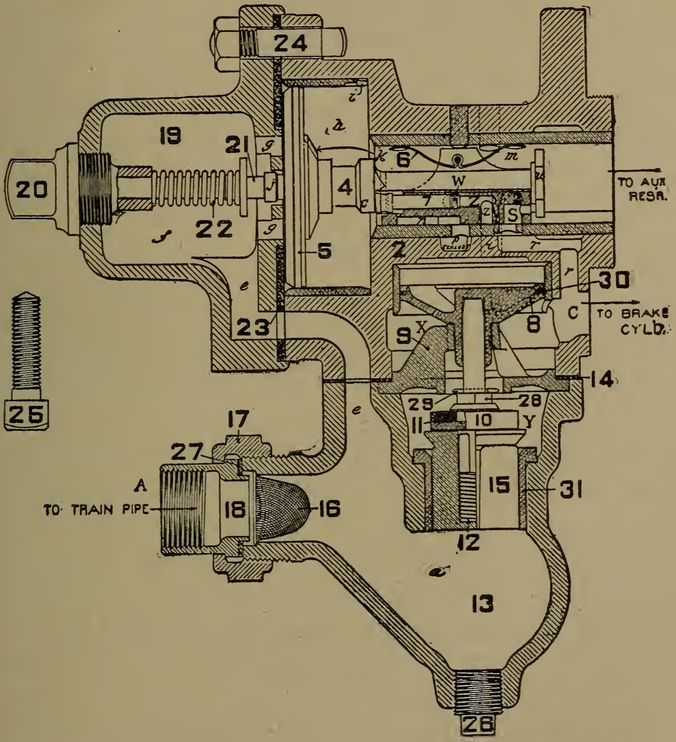


Fig. 86.—Quick Action Triple Valve, Emergency Position.

pressure in cavity *y* above check valve 15 now flows to the brake cylinder. Brake pipe pressure now raises check valve 15, allowing brake pipe pressure to flow to the brake cylinder until the auxiliary and brake pipe pressure equalize in the brake cylinder, when the check valve 15 recloses.

684. The effect of uniting the auxiliary and brake pipe pressures in the brake cylinder in the emergency application of the brakes, is that on account of the large volume of air in the brake pipe, the pressure will equalize at a higher pressure than can be obtained by the auxiliary or brake pipe pressures alone.

THE K-2 TRIPLE VALVE

The K-2 triple valve, like the E T locomotive brake equipment, is fast replacing the older styles of equipment, to keep pace with the improvements and demands of the service.

685. The K-2 triple valve is operated (in so far as the engineer's brake valve is concerned) in just the same way as with the older styles of quick-action triple valves. The advantages of operation obtained by the use of this valve are due to its own action, through its peculiar construction and automatic operation, rather than through any expert knowledge or handling of the brake valve by the engineer.

686. The K-2 triple valve has six positions:—1st, Full release and charging; 2nd, Quick service; 3rd, Full service; 4th, Lap; 5th, Retarded release and recharging; 6th, Emergency.

The advantages claimed for this valve are as follows:—

687. A quick service feature which gives a more uniform

and quicker service application of the brakes on long trains, in quick service application of the brakes.

688. Air from both the auxiliary reservoir and brake pipe enters the brake cylinder. This insures a more certain and quicker service application of the brakes.

689. A uniform release feature which causes the brakes to release on the rear end of a long train as soon as on the head end; this is accomplished by the large volume of air in the head end of the brake pipe forcing the triple valves past release, to retarded release position. As the air in the brake pipe flows toward the rear end of a long train, its volume decreases so that the triples are only forced to release position. When the triple valve is in retarded release, the exhaust of air from the brake cylinder is much slower than when in full release position.

As it is only possible to force the triple piston to retarded release position for about thirty car lengths back of the engine, the brakes on the head end of the train will release much slower than those on the rear end, which will cause a uniform release of the brakes throughout the train.

690. The third important feature of this valve is its uniform recharging feature, which is obtained by decreasing the size of the charging port to the auxiliary reservoir when the triple is in retarded release position. By this means the size of the charging ports is regulated by the difference in the pressure in the head and rear end of the brake pipe.

691. The higher pressure in the head end will thus feed through the small port allowed by the retarded position of the triples, as fast as the low pressure in the rear end of the

brake pipe will feed through the larger port opening of the triple in full release, thus causing the brakes to recharge uniformly throughout the train, preventing brakes sticking and insures a more certain braking power when necessary to reapply the brakes shortly after a release.

THE AIR SIGNAL SYSTEM

692. The air signal system is used on passenger trains as a means of communicating signals from the conductor to the engineer.

693. In general construction the signal system requires: A signal pipe with hose connections to run the full length of the train, branch pipes are connected to the signal pipe under each car, these branch pipes are extended up into each car and are equipped with a conductor's signal valve; to which a cord which runs the full length of the car is attached.

694. The signal pipe is supplied with air from the main reservoir, a reducing valve is placed in the supply pipe which reduces the pressure in the signal pipe to 40 pounds, or the tension of the reducing valve spring.

695. The reducing valve used in connection with the signal system is just the same as the reducing valve used in connection with the independent brake valve. When the E T equipment is used, the signal system pipe is connected to the reducing valve pressure pipe of the independent brake valve.

696. Near the reducing valve is a tee connection in the signal pipe; this branch leads to the signal valve and

whistle. The signal valve and whistle are shown in Fig. 88. The whistle signal valve is used to sound the whistle

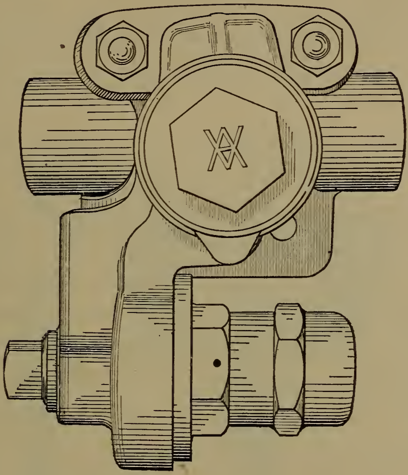


FIG. 87.—C-6 Reducing Valve.

when the pressure in the signal pipe is reduced by opening the conductor's signal valve on any of the cars.

THE AIR WHISTLE SIGNAL VALVE

697. The whistle signal valve controls the flow of air to the signal whistle.

698. The valve contains two operative parts: a rubber diaphragm and signal valve stem.

699. Air pressure enters the valve above the diaphragm

from the signal line through port *d*, thence through passage *c*, into chamber *b*, under the diaphragm. Signal stem 10 is a very loose fit, allowing air to pass freely from passage *c* to chamber *b*.

A reduction in the signal pipe causes a corresponding reduction in the small chamber *a*, above the diaphragm.

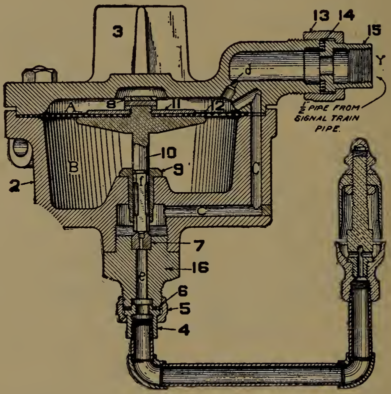


Fig. 88.—Air Whistle Signal Valve.

The pressure in chamber *b* being the greatest, it forces the diaphragm to raise, unseating the signal valve stem 10, allowing air to flow to the whistle, causing it to sound. The same reduction of signal pipe pressure which caused the whistle to sound also caused the feed valve to open, recharging the signal pipe to its normal pressure. This pressure flows into chamber *a*, above the diaphragm, forcing it down, reseating the signal valve.

Air will now pass through cavity *c*, by piston stem 10, into chamber *b*, equalizing on each side of the diaphragm, when the valve is again ready for operation.

700. When the signal is to be sounded, the conductor's signal discharge valve should be held open about one second and then closed for two or three seconds, depending on the length of the signal pipe, when it may be opened again.

701. If the whistle cord is pulled for a series of signals and a sufficient length of time is not allowed to elapse between pulls, the signal valve will not adjust itself to the separate pulls, but will remain open and give one continuous blast of the signal whistle.

702. A leak in the signal pipe will cause the valve to operate and the whistle to sound, giving one blast at intervals which will be determined by the rapidity of the reduction below the feed valve supply.

703. If the whistle does not respond when the conductor's signal valve is opened, the trouble may be in the small port *b*, in the signal valve being stopped up, a dirty strainer, the diaphragm being in bad condition, or there may be too loose a fit of stem 10, in bushing 9.

PRESSURE RETAINING VALVES

704. Pressure retaining valves are used for the purpose of retaining a predetermined amount of pressure in the brake cylinders; to hold the train in check on heavy grades while recharging the auxiliary reservoirs.

705. The use of retaining valves permits of a safer handling of trains on heavy grades; a more uniform

speed; a higher average brake cylinder pressure and a saving in the volume of air necessary to control the train. This saving is accomplished by reason of the fact that the air which is retained in the cylinders will help to increase the pressure to the desired point in successive applications, with a less reduction of brake pipe pressure than would be necessary if the retaining valves were not used.

706. In general construction, a pressure retaining valve is a weight, the lower end of which forms a valve. This weight is enclosed in a casing, the bottom of which forms a valve seat.

707. The retaining valve is usually placed near the hand brake, where it will be convenient of access. It is connected by a pipe with the exhaust port of the triple valve.

708. To operate the retaining valve place the valve handle in a horizontal position. This closes the direct outlet from the retaining valve pipe to the atmosphere and opens a passage through to the under side of the weighted valve.

709. Any pressure over 15 pounds will raise the valve from its seat, allowing the pressure to escape through a small port in the cage until the pressure has reduced to 15 pounds, when the valve will seat, retaining the 15 pounds in the brake cylinder. To release the retaining valve, move the handle down pointing to the ground. In this position the retaining valve is inoperative.

710. The new three-position retaining valve contains two separate weighted valves instead of one; the top valve, being cup-shaped, is inverted and placed over the ordinary valve.

711. When the valve handle is in line with the pipe the valve is inoperative.

712. When the handle is placed at an angle of 45 degrees both weights resist the escape of air, thus retaining about 50 pounds' pressure in the brake cylinder.

713. When the valve handle is placed in a horizontal position, at right angles to the pipe, only one of the weights is effective, retaining about 25 pounds in the brake cylinder.

FACTS TO BE REMEMBERED IN THE OPERATION OF THE AUTOMATIC BRAKE SYSTEM

714. The engineer should inspect the locomotive brake equipment thoroughly before leaving the engine house. Have any defects repaired and so avoid a possible delay to his train.

715. He should see that the air compressor works properly, that the governors are adjusted, and stop the compressor at the required main reservoir pressure.

716. Test the brake valves, to see that they are in good condition and operate the brakes properly, and that the air gauges show the required pressure.

717. When the engine is coupled to the train, a service application of the brakes should be made before turning the air into the train brake pipe.

After the air is turned into the train brake pipe, the brake valve may then be placed in release position until the brakes release and the brake pipe is almost recharged, when the brake valve handle should be moved to running position. This will insure a uniform and full release of all brakes and a quick recharge.

TESTING TRAIN BRAKES

718. After the brake pipe pressure has equalized throughout the train at the required pressure, a service application of the brakes should be made, with a reduction of 20 pounds.

719. After the inspectors have examined each car to see that the brakes are working properly, they will signal the engineer to release brakes.

720. After again examining each car to see that all brakes have released, they will notify the engineer as to how many cars there are in the train and the condition of the air equipment.

721. If the equipment is found defective, the defect must be remedied and again tested the same as before.

APPLYING THE BRAKES

722. When applying the brakes to make a service stop with a long train, a light reduction of from five to seven pounds should first be made, in order to bunch the train, after which any reduction sufficient to control the train may be made. This prevents a sudden shock and possible damage to the rear end of long trains.

723. On passenger trains; the first reduction of brake pipe pressure to make a service stop will depend largely on the condition of the rail, the grade, and the rate of

speed. No definite amount of reduction can be stated which will apply satisfactorily to all conditions.

RELEASING THE BRAKES

724. When an emergency application of the brakes has been made, never release until the train has come to a full stop. Because the brake pipe and auxiliary pressures are reduced so low that to release before coming to a full stop would leave the engineer without sufficient pressure in brake pipe and auxiliary reservoirs to stop the train if immediate occasion required.

725. Another reason for not releasing until the train has come to a full stop is the danger of breaking in two on account of the slack running out.

726. To make a running release after a full service application of the brakes. The rate of speed at which it will be safe to release will depend largely on the length of the train and the style of brake equipment.

727. A train of 50 cars equipped with the ordinary quick-action triple valves and the engine equipped with the G-6 brake valve, it would not be safe to release at a less speed than twelve miles an hour. But, if a train of the same number of cars is equipped with K-2 triple valves and the engine is equipped with the E T equipment, the brakes may be released while running at a considerably less rate of speed.

728. On passenger trains, when making station stops the brakes should be released immediately before the train comes to a full stop. This allows the trucks to settle back

to their normal position, thus reducing the lurch of the cars and the shock of stopping to a minimum.

729. Passenger trains running at a high rate of speed should be steadied on all short curves, by a light service application of the brake. The brake should be applied while on the straight before striking the curve and released just as soon as the trucks have all adjusted themselves to the curvature of the track.

It is not necessary to make a heavy reduction which will retard the movement of the train, but a sufficient reduction of brake pipe pressure must be made to insure all brakes releasing.

730. With trains of eight cars or more a reduction of 10 pounds should be made.

731. A less reduction will cause the brakes to drag.

DISORDERS OF THE AIR BRAKE EQUIPMENT AND THEIR REMEDIES

732. Disorders and failures of the air brake equipment are usually the result of one of four causes:—1st, Air leaks in the piping or operative parts; 2nd, Dirty or gummed valves or cylinders; 3rd, Broken piping or operative parts; 4th, Failure to operate the brake system according to prescribed rules.

733. Air leaks in the piping are usually the result of loose joints and unions, which may be tightened and thus remedy the defects.

734. Leaky operative parts are usually the result of wear and while causing considerable inconvenience, will seldom

cause a complete failure. Such leaks must be reported by the engineer on arrival at the terminal.

735. Dirty or gummed parts are usually the result of neglect to care for the parts properly at the terminal. This condition may be remedied by removing and cleaning the parts.

736. Broken piping or operative parts are usually the result of some accident and require a thorough knowledge of the equipment in making repairs. There are a great many pipes which can be cut out and the brake system still be operative, while other pipes if broken will necessarily cause a complete failure.

Some of the pipes which can be cut out, or blanked by the use of a blind gasket are as follows:—

737. The feed valve pressure pipe leading to the top of the excess pressure head of the pump governor. If this pipe is broken a gasket must also be placed in the main reservoir pressure pipe to the bottom of the excess pressure governor head. But if the pipe connection to the bottom of the excess pressure head is the one broken, a gasket placed in it to stop the loss of air will be all that is necessary, as maximum pressure head will then control the pump.

738. If the main reservoir pressure pipe connection to the maximum pressure head is broken off, double it back on itself and hammer it together. This will prevent the loss of main reservoir pressure. Care must be used, however, not to allow the brake valve to remain too long in lap, service, or emergency positions without cutting down the steam supply to the pump. Because in this position,

with the maximum pressure head cut out or inoperative, there will be nothing to stop the pump.

739. If the governor heads are both inoperative the pump may be run by throttling the steam supply to the pump. By close watching, the train may be moved to the terminal with full braking power.

740. Another pipe which can be dispensed with in case of emergency is the equalizing reservoir connection to the brake valve.

741. If the equalizing reservoir is broken off, blank the pipe connection to the brake valve and plug the service exhaust port opening. Brakes may then be applied by using the emergency position.

742. If any of the gauge pipes become broken, they may be blanked without affecting the operation of the brakes. Great care must be exercised, however, in handling a train with the air gauges inoperative.

743. If any of the brake cylinder branch pipes are broken, cut them out; it will cause the loss of that brake cylinder only.

744. If any of the branch pipe connections to the brake pipes are broken, cut them out. Use the cut-out cock if there is one; if not, use a blind gasket if possible.

745. When it is necessary to plug a tee connection to the main reservoir pipe or brake pipe, care must be used not to stop the flow of air through the main pipe.

746. If the main reservoir branch pipe connection to the distributing valve is broken off, cut it out or plug it. All locomotive brakes will be inoperative.

747. If the application cylinder pipe is broken, blank the opening at the distributing valve. The brakes may now be operated automatically but not independently.

748. If the distributing valve release pipe is broken, the holding position of the automatic brake valve would be inoperative.

The independent brake valve application would be inoperative with the equalizing slide valve in release position.

749. If the brake valve cylinder pipe is broken off, the locomotive brakes will be inoperative. To prevent loss of main reservoir air when an application of the automatic brake valve is made, close the cut-out cock in the main reservoir branch pipe connection to the distributing valve.

750. If the brake pipe branch connection to the distributing valve is broken off, plug the brake pipe to prevent loss of brake pipe air.

751. The application part of the distributing valve can still be operated independently and by the automatic brake valve in emergency position.

752. When a bad leak is apparent by the action of the pumps, place the automatic brake valve on lap position. If the brake pipe pressure drops quickly and the pumps stop running, the leak is in the brake pipe, but if the brake pipe pressure does not drop and the pumps continue to run, the leak is in the reservoir side of the brake valve.

753. If the rotary valve of the automatic brake valve leaks badly, it will cause the train brakes to release when

the brake valve is placed on lap after a service application of the brakes, unless the brake pipe leakage is equal to the rotary valve leakage.

754. To test for a leak in the rotary valve, place the brake valve in lap position. Now open the angle cock in the brake pipe at the rear of the tender and after the brake pipe pressure is exhausted, place the end of the hose in a bucket of water. If the rotary valve is leaking bubbles will appear in the water in the bucket; if it is not leaking no bubbles will appear.

755. If a bad leak should appear in the auxiliary reservoir triple valve or brake cylinder, close the cut-out cock in the branch pipe between the triple and the main brake pipe and open drain cock on auxiliary reservoir. The brake on that vehicle will now be inoperative.

756. If the leak or break should occur between the cut-out cock and the main brake pipe, remove the pipe between the cut-out cock and the main brake pipe; remove the cut-out cock with its good pipe connection, reverse it, and screw it into the brake pipe tee from which the broken pipe was removed. Close the cut-out cock and the brake pipe can be used just the same as before, with the brake inoperative on that car or vehicle.

757. Another way to repair this kind of a leak or break, is to remove the pipe connecting to the brake pipe, drive a plug in it and screw it back in place.

758. If the brake pipe on a passenger car is broken, the car may be retained in the train and the brakes operated on the cars behind it, by disconnecting the signal line and brake pipe hose, at both ends of the car. Now couple the

signal pipe hose to the brake pipe hose at both ends of the car, thus passing brake pipe air through the signal pipe on the defective car, to the brake pipe behind it. The brakes will now be operative on all except the defective car. The signal line will only be operative on the cars between the defective car and the locomotive.

759. If the rotary valve of the independent brake valve is leaking and both brake valves are in running position, there will be a slight blow at the emergency exhaust port of the automatic brake valve.

760. When a partial service application is made with either brake valve and the valve is placed on lap, the pressure in the application chamber of the distributing valve will be increased by the leak in the independent rotary valve.

761. When a partial automatic service application is made and the brake valve returned to lap position, any leakage in the brake pipe equalizing slide valve, graduating valve, or the independent rotary valve will increase the pressure in the application chamber of the distributing valve and cause a corresponding increase in brake cylinder pressure.

762. If a continuous blow occurs at the brake cylinder exhaust port of the distributing valve, the exhaust valve is leaking.

763. When either brake valve is placed on lap, after a service application, any leakage from the application cylinder of the distributing valve will cause the locomotive brakes to release.

764. Failure to operate the brakes according to pre-

scribed rules, may result in delays or serious consequences, and will subject the engineer to discipline, besides stamping him as an incompetent.

765. The remedy for or preventive of this condition lies with the engineer himself, who should lose no time in acquiring a thorough knowledge of the construction and operation of the air brake system.

Part Five

EXTRACT FROM STANDARD RULES

GENERAL DEFINITIONS

766. A Train.—One or more engines coupled with or without cars displaying markers.

767. A Regular Train.—Is one represented on the time table. It may consist of one or more sections.

768. A Section.—One of two or more trains displaying signals or for which signals are displayed and running on the same schedule.

769. Extra Trains.—Are not represented on the time table and are designated as extra, for all extra trains, except work train extra and passenger train extra.

770. Work Train Extras.—Are designated as work extras.

771. Passenger Train Extras.—Are designated as passenger extra.

772. A Superior Train.—Is one having precedence over another train.

773. A Train of Superior Right.—Is one given precedence by train order.

774. A Train of Superior Class.—A train given precedence by time table.

775. A Train of Superior Direction.—A train given

precedence in the direction specified in the time table, as between trains of the same class.

776. A Time Table.—Is the authority for the movement of regular trains subject to the rules.

777. It contains a classified schedule of trains and special instructions relating to their movement and operation.

778. A Schedule.—Is that part of a time table which prescribes the class, direction, number, and movement of a regular train.

779. A Division.—Is that portion of a railroad assigned to the supervision of a superintendent.

780. A Main Track.—Is a track extending through yards and between stations upon which trains are operated by time tables or train orders or the use of which is controlled by block signals.

781. A Siding.—Is an auxiliary track used for the meeting and passing of trains.

782. A Single-Track System.—A main track upon which trains are operated in both directions.

783. A Double-Track System.—Two main tracks, upon one of which the traffic is in a specified direction and upon the other, in the opposite direction.

784. Three or More Tracks.—Three or more main tracks upon any of which the current of traffic may be in either specified direction.

785. A Station.—Is a place designated on the time table by name, at which a train may stop for traffic or to enter or leave the main track or from which fixed signals are operated.

786. A Yard.—Is a system of tracks within defined limits used for the making up of trains, storing of cars and other purposes, over which movements not authorized by time table, or by train order, may be made, subject to prescribed signals and regulations.

787. A Pilot.—Is a person assigned to a train when the engineer or conductor, or both, are not fully acquainted with the physical characteristics of the railroad, or portion of the railroad over which the train is to be moved.

SIGNAL DEFINITIONS

788. A Block.—Is a length of track of defined limits, the use of which by trains is controlled by block signals.

789. A Block Station.—A place from which block signals are operated.

790. Block Signal.—A fixed signal, controlling the use of a block.

791. Home Block Signal.—A fixed signal at the entrance of a block to control trains in entering and using said block.

792. Distant Block Signal.—A fixed signal used in connection with a home (and advance if used) block signal, to regulate the approach thereto.

793. Advance Block Signal.—A fixed signal used in connection with a home block signal to subdivide the block in advance.

794. Block System.—A series of consecutive blocks.

795. Manual Block System.—A block system in which the signals are operated manually.

796. Controlled Manual Block System.—A block system in which the signals are operated manually and so constructed as to require the co-operation of the signal man at both ends of the block to display a clear, or caution, home (or advance if used) signal.

797. Automatic Block System.—A block system in which the signals are operated by electric, pneumatic, or other agency actuated by a train, or by a certain condition affecting the use of a block.

INTERLOCKING SIGNALS

798. Interlocking.—An arrangement of switch, lock, and signal appliances so inter-connected that their movements must succeed each other in a predetermined order.

799. Interlocking Plant.—An assemblage of switch, lock, and signal appliances interlocked.

800. Interlocking Station.—A place from which an interlocking plant is operated.

801. Interlocking Signals.—The fixed signals of an interlocking plant.

802. Home Interlocking Signal.—A fixed signal at the point at which trains are required to stop when the route is not clear.

803. Distant Interlocking Signal.—A fixed signal used in connection with a home interlocking signal to regulate the approach thereto.

804. Dwarf Interlocking Signal.—A low fixed signal.

THE TIME TABLE

805. Each time table shows a list of stations on its face, under the number of each train and opposite the name of each station, the time of the train at that station is shown.

806. Not more than two times are given for a train at any point.

807. Where one is given it is, unless otherwise specified, the leaving time.

808. Where two are shown, one is the arriving time and the other is the leaving time.

809. Trains must not arrive ahead of their arriving time, or leave ahead of their leaving time.

810. Where trains are scheduled to meet at any point, the time for the train at that point is shown in full-faced type.

811. The number of the train to be met or passed will appear in small type immediately adjoining the full-faced type.

812. To the left of the lists of station names is shown a mileage list, so that the engineer may know the number of miles he has to run his train.

813. The distance between stations is shown in figures, between the names of the stations.

814. The letter S shown before the time of the train indicates that the station for which the time is shown is a regular stop for that train.

815. The letter F indicates that stations for which the time is shown is a flag stop for that train.

816. The letter D stands for day; N, for night; D and N, day and night telegraph offices.

817. Other small letters are shown for certain trains at designated stations. These letters refer to special rules regarding the train at that point.

818. On the front of each time table is shown the number of the time table, the date and hour it takes effect.

819. Trains are designated as first-, second-, and third-class, and extras.

820. Extras are not listed in the schedule.

821. A first-class train is superior to a second-class train.

822. A second-class train is superior to a third-class train.

823. Extra trains have no class or right except those conferred by general order or train order.

TRAIN PROTECTION

824. If an accident occurs to the train, the engineer must see that other tracks which may be obstructed are protected at once, notifying all trains to look out for obstructions on the track, until the extent of the damage has been ascertained, when if the other tracks are not obstructed, the protection may be recalled from those tracks.

825. When a train stops or becomes delayed, so that it may be overtaken by another train, the flagman must go back immediately with stop signals a sufficient distance to insure full protection. When recalled he may return to his train, first placing two torpedoes on the rail when the conditions require it.

826. The front of the train must be protected by the fireman when the conditions require it.

827. Trains must approach the end of double track, junctions, railroad crossings at grade and drawbridges prepared to stop, and not proceed until the signals are right and the track clear.

828. Where required by law trains must stop.

829. Engineers and conductors are held responsible for the safe movement of their trains and must take every precaution for their protection and run no risks.

830. The operating rules of the different roads usually have some features which distinguish them as belonging to that particular system, so that no hard and fast rule can be laid down as the standard on all roads. Therefore the student must familiarize himself with the operating rules used on the system on which he works.

THE LOCOMOTIVE ENGINEER

831. The duties and requirements of a locomotive engineer are very numerous and diverse.

He must report for duty at a designated time and place, secure a time slip, sign an order for the necessary supplies for the trip, examine the bulletin and general order board and sign all new general orders.

He must then prepare his locomotive for the trip.

He must know that the injectors, air pump, and lubricators are in working condition and observe the condition of the fire-box sheets.

While oiling around he must observe the condition of the machinery.

He must know that the proper supply of water, coal, and sand are on the locomotive, that the sand blowers are in working condition, as well as the signal equipment.

He will then move the locomotive to the yard or place designated, couple to the train, and test the air brakes on the train to see that they work properly when operated from the locomotive.

He must compare time with the conductor. He is then ready to move the train subject to the rules governing the movement of trains.

He must exercise good judgment at all times in starting, running, stopping the train and shifting of cars, so as to avoid injury to persons or property.

He must keep a constant lookout on the track ahead to observe signals or the appearance of danger. He must not permit burning waste on the locomotive, or hot cinders to be thrown from the locomotive along the right of way, and not allow the front end or ash pan to be cleaned except at designated points. He must show all orders to the fireman and explain them if requested to do so. He must call the indication of signals to his fireman.

He must not permit unauthorized persons to ride on the locomotive.

He must not leave the locomotive except in case of necessity and then must leave the fireman in charge.

On arrival at the terminal he is required to turn in a time slip for the trip, showing mileage and actual time on duty. Make out a work report of all necessary repairs and general condition of locomotive.

He is also required to make a report regarding all cases of personal injury, break-downs, and causes of delay to the locomotive.

He is then relieved until time to report for the next trip.

ECONOMICAL OPERATION

832. A thorough knowledge of the physical condition of the road is absolutely necessary to the successful and economical handling of trains. With this knowledge the engineer can run his locomotive more economically and make better time with less waste of energy.

833. When starting a train, the reverse lever should be placed at full stroke, with a light throttle. As the locomotive increases speed the reverse lever should be moved gradually to as near the center as the required speed of the train will permit. As the reverse lever is being notched up, the throttle should be opened in proportion, so that when the reverse lever is hooked up just as far as good service will permit, the throttle will be wide open. Now ease off on the throttle slightly. This will not wire-draw the steam, but will relieve the valves of some of the excess pressure under which they are working and which the cylinders are not using. This will cause the engine to run free and attain a higher rate of speed.

834. Every mile an engine is run with the reverse lever one notch lower in the quadrant than is necessary, is just so much energy wasted.

835. Every drop of oil that is spilled and poured on an engine and does not reach the bearings for which it was intended, is a waste of supplies.

836. Every engineer should practice economy in the use of supplies and the running of the locomotive.

PERSONAL INJURIES

837. Every locomotive engineer should know what to do in case of personal injury, as such accidents are always liable to occur at any time, sometimes a long distance from a doctor or other assistance.

838. If a leg is cut off, bind a cord around the stump a few inches back of the injured part, put a binder in this cord and twist it until the flow of blood is stopped, place the patient in as comfortable a position as possible, and secure medical aid.

839. If the flesh is torn or cut and the parts not severed, bind the parts closely with a handkerchief or piece of a shirt. If the bleeding is too profuse, bind the parts the same as for a severed limb.

840. If an artery is severed, place a binder between the body and the cut.

841. If a vein is severed, place the binder on the side of the cut farthest from the body.

842. Arterial blood flows direct from the heart to the extremities and flows by spurts at each pulsation of the heart and is bright red in color, the blood in the veins runs with a steady flow and runs from the extremities toward the heart and is dark red in color.

843. The difference in the direction of the flow of the blood in the arteries and veins makes necessary the difference in the location of the bandage to stop the flow of blood.

844. If a leg or arm is broken, straighten the limb and lash to a board, so that the fracture will not be irritated while the patient is being moved.

845. In case of scalds or burns, saturate the parts with valve oil, then bind loosely, to keep out the air and the skin from sloughing from the burn.

846. In case injured persons become unconscious, they can sometimes be revived by dashing a little cold water in their face, or applying a little to the back of head and neck. However, if the fainting is caused by loss of blood, the patient must be kept warm.

847. In case of a fall, or electric shock, move the arms from the side to above the head; then press them forcibly on the breast and return to the side. Repeat this slowly until the patient shows signs of breathing. Chafe the arms, wrists and ankles, massage the legs and arms to keep up circulation until the patient recovers his breath and becomes conscious.

848. If the injury is about the body, so that the foregoing rules cannot be observed, bind a towel (almost every engineer carries a towel with him) so as to hold the parts together, place the injured person on a stretcher and move carefully to the nearest doctor or hospital.

DEPORTMENT

849. Every engineer should endeavor to maintain the high standard of his calling, by precept and example. Although he has become an expert engineer and deserves a certain amount of consideration on account of his knowledge and ability, yet he must not consider himself any better than his fireman on that account, because the fireman may be his superior in every other way. Therefore the position does not make the man.

850. The fireman of to-day becomes the engineer of to-morrow and should be treated with all due courtesy and respect.

The engineer of to-day was the fireman of yesterday and he should remember how he desired his engineer to treat him.

If the engineer meets his fireman as a man, the fireman will not presume upon his kindness.

851. If each one will co-operate with the other in the performance of his duties, he will be enabled to give better service to his employers.

Part Six

QUESTIONS FOR EXAMINATION

The questions here listed are fully answered in the descriptive matter pertaining to each subject.

The answer to each question bears the same number as the question beginning at number one and continuing in their regular order throughout the book—for example, question No. 9 is answered by paragraph No. 9, question No. 96 is answered by paragraph No. 96. By this method the student will have the real knowledge of the answer impressed upon his mind. The student will know in his own mind when reading the question as to whether he can answer it or not. If he can answer it, well and good, but if he cannot answer it, he can have the answer by turning to the paragraph of the same number as the question.

This method of study has the approval of railway officials and the indorsement of the foremost educators of the present time.

THE FIREMAN'S DUTIES

1. What is required of the student fireman before the engineer will sign him up as being capable of performing the duties of a locomotive fireman?

2. When must the fireman report for duty?

3. What must he examine before starting on each trip?

4. What must he assist in placing on the engine?

5. What necessary equipment is supposed to remain permanently on the engine?

6. What attention must be given to the signal equipment?

7. Of what does the signal equipment consist?

8. When must the head-light, lanterns, and markers be lighted? When put out?

9. By whose instruction will the classification lights be lighted and set to show green or white?

HOW TO FILL THE LUBRICATOR, AND OTHER DUTIES

10. What is the first move to be made when about to fill a lubricator?

11. Explain in detail the operation of filling a lubricator.

12. After filling the lubricator what is the fireman required to do?

13. What attention must now be given the fire?

14. What steam pressure will the fireman endeavor to maintain while on the road? What should the average be?

15. What are the fireman's duties while on the road?

16. When will the fireman take charge of the engine? What must he not do?

17. When is the fireman required to protect the front end of the train?

18. At the end of the trip, what will the fireman assist in doing when required?

19. From what is the fireman's time taken?
20. When is the fireman relieved from duty?
21. With what must the fireman be familiar?
22. To whom does the fireman report and receive his instructions?
23. Whose orders must he obey?
24. When at the engine house whose direction is he under?
25. When with the engine whose order must he obey?

SIGNALS USED IN TRAIN SERVICE

COLOR SIGNALS

26. Give the meaning of the following color signals: Red? White? Green? Green and white? Blue?
27. Explain the use of a fusee.

HAND, FLAG, AND LAMP SIGNALS

28. Explain how the following signals should be given when using the hand, flag, or lamp. Stop? Proceed? Back? Train parted? Reduce speed? Apply air brakes? Release air brakes? What is the meaning of any object waved violently on or near the track?

ENGINE STEAM WHISTLE SIGNALS

29. Explain the meaning of the following steam whistle signals. One short? Two long? One long, three short? Four long? Four long, one short? Five long? Five long, one short? Three long? Three short when train is standing? Three short when train is running? Four short?

Two short? One long, two short? Two long, two short? One long? A succession of short blasts? Explain the use of torpedoes.

AIR WHISTLE SIGNALS USED IN PASSENGER SERVICE

30. What is the air whistle signal to start? Stop at once? Back? Stop at next station? Apply or release air brakes? Reduce speed? Call flag? Increase speed?

COMBUSTION

31. Why should the fireman and engineer have some knowledge of combustion?

32. What is generally known as combustion?

33. How is combustion accomplished? What is thrown off? What is absorbed?

34. What is the composition of bituminous coal?

35. What is the composition of the atmosphere?

36. What is the composition of water?

37. What is carbon?

38. What is carbon dioxide?

39. What is carbon monoxide?

40. What is hydrogen?

41. What is oxygen?

42. What is nitrogen?

43. What is the minimum quantity of air required for the combustion of one pound of bituminous coal?

44. How many parts of carbon and oxygen unite to form carbon dioxide?

45. When heat is first applied to the coal, what is first expelled and burned?

46. Does an excess of carbon in the coal produce more or less flame?

47. Give the regular order in which the elements contained in coal are consumed.

48. What does hydrogen and carbon when combined with oxygen produce?

49. What are the results of complete combustion?

50. What are the results of incomplete combustion?

51. Explain what takes place when building a new fire?

52. Does the temperature of new fuel exert any influence on the temperature of the furnace?

53. What temperature is necessary to ignite and burn the gases produced from new fuel?

54. What will be the result if a large quantity of coal is fired at each firing?

55. How should coal be fired to give the greatest efficiency?

56. What is the composition of smoke?

57. Upon what does the density of smoke depend?

58. What is a British thermal unit?

59. How many heat units will one pound of coal produce?

60. How many pounds of water will one pound of coal evaporate?

61. What causes a loss in general efficiency?

62. What is the rate of combustion per square foot of grate surface per hour?

63. What is the average evaporation per pound of coal?

64. What is the weight of one gallon of water?

65. What is just as essential as coal to produce perfect combustion?

66. How many pounds or cubic feet of air per pound of coal is necessary to insure complete combustion?

67. Should the supply of air to the furnace be regulated?

68. What will be the result if too much air is admitted to the furnace?

69. How should air be admitted to the furnace?

70. Explain how the draft affects combustion.

71. What will be the result if sufficient oxygen is not present during the process of combustion? If a fresh supply of air is admitted to the surface of the fire what will be the result?

72. What beneficial results may be obtained by regulating the fire door damper?

73. How should the ash pan dampers be regulated?

74. What is the highest temperature that can be maintained in the fire box under ordinary conditions?

75. What absorbs the heat from the furnace?

METHODS OF FIRING

76. How many systems of firing are there?

77. Explain the coking or bank fire.

78. Explain the graduated or wedge-shaped fire.

79. Explain the level fire.

80. What method of firing is recommended for the small fire box? For the large wide fire box?

81. What is required while working in city limits?

82. How should an engine be fired to produce the best results with a minimum volume of smoke?

83. Explain the use of the fire hook? What will be the result of careless or excess hooking?

84. What care should be exercised when shaking the grates at the beginning of a trip?

85. When should the grates be shaken?

86. How should the dampers be adjusted to produce the best results?

87. Why should the fire door be closed between each shovelful of coal?

88. Explain the use of the blower.

89. What should be done if the water becomes dangerously low in the boiler?

The Boiler

GENERAL DESCRIPTION OF THE LOCOMOTIVE, ITS CONSTRUCTION AND OPERATION

THE BOILER

90. What is a locomotive boiler?

91. What style of boilers are used in locomotive construction?

92. What kind of material is used in the construction of locomotive boilers? To what tests are they subject before being used?

93. For what qualities are boiler plates carefully tested?

94. Why are they tested for tensile strength?

95. Why are they tested for toughness and elasticity?

96. Why are they tested for ductility?

97. How are the boiler plates fastened together?

98. Why are longitudinal seams riveted with a less number of rivets than circumferential seams?

99. What is the difference in the strength of single-riveted lap joints and double-riveted lap joints?

100. What kind of joints are used for longitudinal seams? What kind of joints are used for circumferential seams?

101. How is a butt joint constructed?

102. Of how many sheets is the fire box constructed? Name them.

103. Explain where the fire box is placed and by what means it is connected at the bottom to the shell.

104. By what means are the side sheets, door sheet, and part of the flue sheet connected to the outer shell?

105. How is the crown sheet supported?

106. Why does the barrel of a boiler need no staying?

107. Why must flat surfaces be stayed?

108. What is the water leg of a boiler?

109. Where is the dome placed on the boiler and for what purpose? What is placed in the dome?

110. How is the flue sheet held in place?

111. What part of the boiler is called the throat sheet?

112. What part of the boiler is called the barrel?

113. What is placed in the front end or smoke box?

114. Name the different parts of the boiler.

115. Why are hand holes provided in the sides of the smoke box?

116. For what purpose is a blow-off cock placed in the throat sheet?

117. For what purpose are removable plugs and plates placed at different places in the shell of the boiler?

118. Where is the safety valve located? What is its use?

119. What style of fire box is generally used?

120. In what position is the boiler placed on the frames?

THE ENGINES

121. What two kinds of engines are used in locomotive construction?

122. What is a simple engine?

123. Explain the action of the simple locomotive engine.

124. What is a compound engine?

125. Explain the action of the compound locomotive engine.

126. How do the simple and compound locomotives compare in general performance?

127. How many engines has each locomotive? In what position are they attached to the frames?

128. By what means are the two engines connected?

129. Explain the relation or position of one engine to the other.

130. For what purpose is the locomotive designed?

131. How are all the driving wheels of an engine connected and for what purpose?

132. To what is the cylinder saddle connected and for what purpose? What ports does it contain?

133. What other two ports are cast in the cylinder casting?

134. What parts convey the power from the cylinder to the main pin?

135. How is the reciprocating motion of the piston changed to circular motion?

136. Explain the action which takes place when steam is admitted to the cylinders.

137. What will be the result if the crank pin is at a point which forms an angle to the center line of motion?

138. What will be the result if the pin is on the center line?

139. How many centers has each engine?

140. When is the engine on its forward center?

141. When is the engine on its back center?

142. What are the forward and back centers of an engine sometimes called? What carries the pin past the center?

143. What means is used with stationary engines to carry the engine over the center? Why can this method not be used with locomotives?

144. Explain what takes place when changing the reciprocating motion of the piston to the circular motion of the crank pin.

145. Explain why the angularity of the main rod causes the cross-head to travel farther and faster during the movement of the crank pin from the forward center to the bottom quarter, than it does from the bottom quarter to the back center.

146. Explain the reason for the seemingly erratic movement of the cross-head.

147. With the cross-head at the exact center of its stroke, will the main rod reach to the exact top or bottom quarter line?

148. Why does the angularity of the main rod increase during the first part of the stroke and decrease during the latter part of the stroke?

149. At what points in the stroke is the greatest pressure exerted on the crank pin?

150. Does the unequal pressure on the crank pin cause it to wear uneven?

THE PISTONS

151. Explain the construction of a piston.

152. How is steam prevented from leaking past the piston head?

153. How is the piston rod attached to the cross-head?

CROSS-HEAD AND GUIDES

154. Why are guides and a cross-head necessary?

155. If a cross-head and guides were not used, what would be the result?

156. To what are the guides attached?

157. What style of guides are generally used?

158. Explain the construction of a cross-head.

159. Is the pressure the same on both the top and bottom guide bars?

160. Explain why the pressures on the guides are unequal.

MAIN RODS

161. Why are main rods made I-shaped?

162. How is the crank or butt end of the main rod constructed?

163. Explain the manner of keying up the front end of the main rod.

PARALLEL RODS

164. Explain how the bearings are placed in the parallel or side rods. What is the difference between the old and

new method of construction? Why must great care be exercised in the adjustment of the keys in the parallel rods?

THE DRIVING WHEELS

165. Explain the method of putting a tire on a driving wheel center.

166. Why are driving wheels provided with counterbalances?

167. Where is the counterbalance placed and why is it so placed?

168. Can any advantage be gained by adding additional overweight to the counterbalance?

THE CRANK PINS

169. What kind of material is generally used for crank pins?

170. Explain how the pins are placed in the wheels.

171. Explain how the collars are made and fastened to the pins to hold the rods from slipping off the pins.

THE DRIVING AXLES

172. Of what kind of material are driving axles made?

173. How are driving axles now made?

174. What pressure is used to press the wheels on the axles?

LOCOMOTIVE FRAMES

175. Of what kind of material are locomotive frames made? To what test are they subject?

DRIVING BOXES

176. Give a general description of a driving box.

177. Why are shoes placed between the driving box and the pedestals?

178. Explain the purpose and manner of adjusting driving box wedges.

179. Where is the oil cellar located? What is it filled with?

180. What is the purpose of the small holes which are drilled in the top of the driving boxes?

THE SPRING SADDLE

181. Explain the use of a spring saddle.

THE DRIVING SPRINGS

182. Why are driving springs used?

183. Explain the construction of a driving spring.

SPRING HANGERS

184. What is a spring hanger?

EQUALIZERS

185. What are equalizers used for?

ENGINE TRUCKS

186. For what purpose are engine trucks used?

187. Explain the construction of the four-wheeled or bogie truck.

188. What other style of truck is used?

THE VALVES

189. What are the valves used for?

190. What two kinds of valves are generally used?

THE SLIDE VALVES

191. What type of slide valve is generally used? What other style of valve is coming into general favor?

192. Give a general description of a balanced slide valve. What are balance strips used for? What holds the strips in place?

193. Explain the most simple form of slide valve.

194. When the simple slide valve is used, is steam admitted to and exhausted from the cylinder during the entire stroke?

195. In order to use the steam expansively, how are slide valves now made?

196. What occurs when the valve is moved to one side of its central position on its seat?

THE ALLEN VALVE

197. Explain the construction of the Allen or Allen-Richardson Valve. What is the purpose of the supplementary arch?

THE PISTON VALVE

198. What feature of the piston valve is causing it to be generally used?

199. What is meant by inside admission?

200. What is meant by outside admission?

201. Explain the form and construction of the valve seat.

LAP

202. What is lap, as applied to the valves of a locomotive?

203. What is lap used for?

204. What is outside lap?

205. What is inside lap?

206. What does inside lap control?

LEAD

207. What is lead as applied to the valves of a locomotive?

208. Why are valves set with lead?

209. Explain in detail why lead is necessary.

210. When is the necessity for lead only apparent? Why?

211. What is the proper amount of lead to give the valves when set in the ordinary running position?

VALVE GEARS

212. What is meant by valve gears?

213. What styles of valve gears are most generally used?

THE STEPHENSON VALVE GEAR

214. Give a general description of the construction of the Stephenson valve gear.

215. Why is a disc eccentric used? What advantage has it over the common crank?

216. How are the eccentric blocks which control the movement of the engine designated?

217. What distance equals one-half the throw of the eccentric?

218. Does the travel of the valve at full stroke equal the full throw of the eccentric?

219. How is the eccentric strap in which the blocks works connected to the link? Which eccentric rod is usually attached to the top of the link?

220. What is a link and to what radius is it curved?

221. What is meant by the radius of the eccentric rod?

222. What is placed in the slot in the link? What is attached to the link block? Name the different parts through which motion is transmitted from the link to the valve.

223. By what means are the links raised or lowered?

224. What change takes place when the links are raised or lowered?

225. Explain how the position of the link block affects the valve travel.

THE SADDLE PIN

226. Why is the saddle pin set out of center on the link?

THE CUT-OFF

227. What is meant by the cut-off?

228. When the link block is near the end of the link, when will the cut-off occur? When the link block is near the center of the link, when will the cut-off occur?

229. With the Stephenson valve gear, what causes the lead to increase as the valve travel is shortened?

THE SLIDE VALVE OPERATED BY THE STEPHENSON VALVE GEAR

230. When the main pin is on the forward center, what is the position of the forward motion eccentric?

231. What is meant by angular advance? Why is it used?

232. If the valve had no lap or lead how should the eccentric be set?

233. What is the relation of the back motion eccentric to the pin?

234. Explain how motion is transmitted from the eccentric to the valve to overcome lap and produce lead.

235. Explain in detail the movement of the eccentric, valve and main pin and their relation to each other during one complete stroke.

236. Which eccentric controls the valve when the engine is reversed?

237. By what are the points of cut-off and direction of motion controlled?

THE ALLEN VALVE GEAR

238. What kind of a link has the Allen valve gear? Where are the forward and backward motion eccentric rods attached to the link?

239. With the engine in the forward motion what will be the position of the link?

240. By what means is the valve motion reversed with this gear?

241. Is the Allen valve essentially a part of this gear?

THE WALSCHAERT VALVE GEAR

242. What is considered one of the most important features of this gear?

243. Name the different parts of this gear.

244. What kind of a link is used?

245. To what radius is the link curved?

246. When the engine is reversed, which is moved, the link block or the link?

247. Does the position of the main pin have any influence upon the movement of the valve by the reverse lever, when reversing the engine?

248. What part of this gear controls the lap and lead?

249. Explain why the lap and lead is independent of the eccentric rod and link.

250. When an outside admission valve is used how is the eccentric crank set in relation to the main pin?

251. When an inside admission valve is used how is the eccentric crank set in relation to the main pin?

252. Why is the position of the eccentric crank in its relation to the pin sometimes changed from its position of 90 degrees ahead or back of the pin?

253. With the cross-head and piston in the center of the stroke will the main pin be on the exact quarter?

254. Is it necessary to make any change in the adjust-

ment of the Walschaert gear to offset the angularity of the main rod?

DIRECT AND INDIRECT MOTION

255. What causes an engine to be direct in the forward motion?

256. What causes an engine to be indirect in the backward motion?

257. With an inside admission valve, where is the radius rod connected to the combination lever?

258. If an outside admission valve is used, where would the radius rod be connected to the combination lever? Why is a valve stem support or guide provided?

THE RELATIVE POSITIONS OF THE VALVE, MAIN PIN, AND ECCENTRIC OF THE WALSCHAERT VALVE GEAR WITH INSIDE ADMISSION VALVES

259. Give a detailed explanation of the movement of the Walschaert valve gear, during one complete stroke of the piston, beginning with the main pin on the forward center, and the reverse lever in the forward motion.

260. How is the constant lead of the Walschaert valve gear obtained?

VALVE SETTING

261. What knowledge should every engineer have of valve setting?

262. Explain in detail how to set the valves with the Stephenson valve gear.

263. Explain in detail how to set the valves with the Walschaert valve gear.

264. Are the different parts of the Walschaert gear made subject to change? When absolutely necessary what parts may be adjusted?

INJECTORS

265. What are injectors used for?

266. How are they designated?

267. What is a lifting injector?

268. What is a non-lifting injector?

269. What connects the injector and the water space in the tank? How is the supply regulated?

270. By what means does the injector get its steam from the boiler?

271. Through what does the water and steam pass from the injector to the boiler?

272. What is placed in the end of the branch pipe?

273. Name the different parts of the injector?

TO OPERATE THE INJECTOR

274. Explain how a lifting injector should be started and what takes place in the injector.

275. How does the injector force the water into the boiler?

276. Explain the theory of injector action.

277. To what part of the boiler is water usually supplied? Why is this necessary?

278. On locomotives having the delivery pipe connected to the boiler head, where is the water delivered in the boiler.

INJECTOR DEFECTS

279. What is absolutely necessary in the supply pipe with lifting injectors?

280. Why is it necessary to have atmospheric pressure on the water in the tank?

281. When an injector fails and the cause is not known what should be done?

282. If the injector still refuses to prime or lift the water what may be the cause?

283. If the injector primes all right but refuses to force water into the boiler what may be the cause?

284. What is the cause of injectors spilling water at the overflow?

TO USE THE INJECTOR AS A HEATER

285. How may the injector be used as a heater? Why should the front or drain cock in the branch pipe be opened?

286. How should the heater be shut off?

287. What care should be exercised to keep both injectors in working condition?

288. What special attention should always be given to the injectors before leaving a terminal?

INJECTORS LEAKING STEAM AT OVERFLOW

289. What may be the cause of an injector leaking steam at the overflow?

290. How may these leaks be tested?

TO TEST FOR LEAKS IN THE SUPPLY PIPE

291. How may the supply pipe to the injector be tested for leaks?

LUBRICATORS

291 *a*. What are lubricators used for?

292. Give a general description of how the lubricator is constructed.

293. What takes place when steam is admitted into the condensing chamber?

294. When condensing valve *D* is opened where does the water from the condensing chamber go?

295. Explain how the water which is admitted into the bowl of the lubricator, with the oil, causes it to operate.

296. What are equalizing pressure pipes and how are they used?

NAMES OF DIFFERENT PARTS OF THE LUBRICATOR

297. Name the different parts of the lubricator.

298. Why must lubricators be operated exactly according to directions?

299. If the sight feed glasses become stopped up, what should be done?

300. When the feed valve nipples become stopped up, how may they be cleaned out?

301. Why should the bowl of lubricator be cleaned out at frequent intervals?

302. What is the most frequent cause of erratic action in the lubricator?

303. What kinds of choke plugs are used?

304. Where are the choke plugs now usually located? What is the effect on the lubricator when the choke plugs are badly worn?

305. After filling the lubricator with oil, why should the condensing valve be opened at once?

306. When is it necessary to fill the lubricator on the road? How may it be operated at once without waiting for it to condense?

THE McCORD FORCE FEED LUBRICATOR

307. Explain the general construction of the McCord force feed lubricator.

308. How are the pumps operated?

309. Name the different parts of the lubricator.

310. How should this lubricator be filled?

311. Explain in detail the operation of the force feed lubricator.

312. How is the feed adjusted?

313. Can the individual pumps be operated by hand?

THE TRANSFORMER

314. Name the different parts of the transformer.

315. Explain the operation of the transformer.

316. How is the wear in the transformer case reduced to a minimum?

317. How is leakage prevented around the shafting?

318. Does this lubricator require any pressure in the oil reservoir or sight feed glasses?

319. Does the lubricator stop feeding when the engine stops?

320. Can the reservoir be filled while the lubricator is in operation?

321. Is the feed adjustable?

322. Will the lubricator work against back pressure or resistance?

THE STEAM GAUGE

323. Is the boiler pressure as indicated on the steam gauge reckoned from absolute or atmospheric pressures?

324. How may the absolute pressure on the boiler be found?

325. How are steam gauges for locomotives usually made?

326. Why are coils placed in the pipe to the steam gauge? Is there water or steam in the gauge? What effect has the pressure in the curved tube in the gauge?

327. What would be the effect on the gauge if a leak should drain the water out of the feed pipe?

328. What should be done when the gauge and safety valve do not indicate the same maximum pressures?

329. What should be done when the safety valve refuses to raise at the pressure for which it is set?

GAUGE COCKS

330. What are gauge cocks?

331. What are the gauge cocks used for?

332. What is the water glass used for?

THE WHISTLE AND BELL

333. What are the whistle and bell used for?

334. When is the engineer required to sound a warning?

335. When must the engine bell be rung?

THE WATER SUPPLY

336. How should the water be supplied to the boiler? Is flooding or priming detrimental?

337. What is the proper depth of water to be carried in most boilers?

338. Why should great care be exercised in supplying water to the boiler?

339. Does the operation of the injector take any heat or pressure from the boiler?

340. How many cubic feet of steam are required to each gallon of feed water?

341. How may water be supplied to the boiler in the most economical manner?

342. Why does irregular pumping often result in engine failures?

343. How will the careful, economical engineer regulate the water supply?

WATER FOAMING

344. Is foaming a dangerous condition?

345. How is foaming usually first detected?

346. How will the exhaust sound? What other indications will appear at the same time?

347. How should the test for foaming be made?

THE CAUSE OF FOAMING AND ITS REMEDIES

348. Name some of the most common causes of foaming. Does mineral oil cause foaming?

349. What effect does carbon oil have when injected into the boiler with the feed water?

350. How may blue vitriol be used?

351. When oil or grease has gotten into the tank, how may it be removed?

352. How may the surface cock be used?

353. If the blow-off cock is opened, what care should be exercised?

354. How may scale be removed from the valve of the blow-off cock.

355. When running with bad water, how may the engine be run to the best advantage?

PRIMING

356. What is the cause of priming and how may it be detected?

357. Why is priming detrimental to the engine?

STEAM—WHAT IT IS AND HOW GENERATED

358. What is steam?

359. At what temperature is steam generated?

360. With a boiler pressure of 180 pounds per square inch, what will be the temperature of the water and steam in the boiler?

361. What are the expansive properties of steam at 180 pounds pressure?

362. To what is the expansive property of steam due?

363. Since it has been shown that the expansive property of steam is due to the heat which it has absorbed, what else does this also prove?

364. What two conditions of steam are there?

365. What is saturated steam?

366. Upon what does the temperature of saturated steam depend?

367. How may saturated steam be superheated?

368. In order to superheat steam, why must it be separated from the water in the boiler?

369. Why is the term saturated steam often misunderstood?

370. What kind of steam passes through the throttle valve, to operate the engines?

371. What per cent of moisture may dry steam contain before it is called wet steam?

372. Is there any moisture apparent in superheated steam?

HOW STEAM PASSES THROUGH THE ENGINE AND OPERATES IT

373. Trace the steam from the boiler through the engine to the open air, explaining the work that it does during its passage.

NAMES OF PRINCIPAL PARTS OF THE LOCOMOTIVE

374. Why is it necessary to know the names of the different parts of the locomotive?

375. Name the different parts of the boiler.

376. Name the different parts of the engine.

LOCOMOTIVE BREAK-DOWNS AND THEIR REMEDIES

377. What is the first thing to do when a break-down occurs?

378. What is the next most important thing to do?

379. In case of accident, who must be notified as soon as possible?

FRONT CYLINDER HEAD

380. If a front cylinder head is knocked out, what should be done?

BACK CYLINDER HEAD

381. If a back cylinder head is knocked out or badly damaged, what should be done?

CROSS-HEAD

382. If a cross-head is badly broken so that it will not slide in the guides with safety, what should be done?

MAIN ROD

383. If a main rod is bent or broken, what should be done?

SIDE RODS

384. If a forward or back side rod connection is broken, what should be done?

385. If a main connection, what should be done?

MAIN PIN

386. What should be done when a main pin is broken off close to the wheel?

FRONT, BACK, OR INTERMEDIATE PINS

387. When a front, back or intermediate pin is broken, what should be done?

MAIN AXLE

388. What should be done when a main axle is bent or broken between the frames?

389. If the main axle is broken off just outside of the box, what should be done?

FRONT AXLE

390. If the front axle is broken between the frames, what should be done?

391. What should be done if the wheel is broken off outside of the driving box?

INTERMEDIATE AXLE

392. If an intermediate axle is broken between the frames, what will be necessary?

REAR AXLE

393. If a rear axle is broken or damaged so that it will not turn or carry its share of the weight, what should be done?

394. If the rear wheel is broken off outside of the driving box, what should be done?

BROKEN TIRE

395. When a tire breaks, what should be done?

TO REMOVE FRONT SIDE ROD CONNECTIONS

396. How may the front side rod connections be removed from an H-6*a* or H-6*b* engine?

397. In what other way may the front side rod connection be removed?

TO REMOVE THE VALVE STEM PIN FROM THE ROCKER ARM

398. How may the valve stem pin be removed from the rocker arm?

BROKEN VALVE YOKE

399. How may the valve be blocked when the yoke is broken?

MAIN STEAM VALVE, STEAM PIPE, OR STEAM CHEST

400. When a main steam valve, steam pipe, or steam chest is broken what is necessary?

BROKEN ECCENTRIC STRAP OR ROD

401. What must be done when one eccentric strap or rod is broken?

BROKEN SPRING, SPRING HANGER, OR EQUALIZER

402. What must be done when a spring, spring hanger. or equalizer is broken?

403. If a long truck equalizer breaks, what should be done?

BROKEN REVERSE LEVER, REACH ROD, LINK HANGER, OR TUMBLING SHAFT

404. When a reverse lever, reach rod, link hanger, or tumbling shaft is broken, what should be done?

BREAK-DOWNS OF THE WALSCHAERT VALVE GEAR

405. Is there any difference in the valves used with the Walschaert valve gear and those used with other styles of valve gears?

406. When disconnecting engines equipped with the Walschaert valve gear, up to what point do the same rules apply as for the Stephenson valve gear?

407. When the valve gear itself is not injured, but for some other reason the valve must be clamped central on its seat, what should be done?

BROKEN ECCENTRIC ROD

408. When the eccentric rod is broken, how should the gear be disconnected?

BROKEN ECCENTRIC CRANK OR LINK EXTENSION

409. What should be done, in case of a broken eccentric crank or link extension?

BROKEN LIFT SHAFT OR RADIUS ROD HANGER

410. Explain what should be done when the lift shaft or radius rod hanger breaks.

BROKEN RADIUS ROD

411. If a radius rod is broken, what should be done?

BROKEN CROSS-HEAD ARM

412. If a cross-head arm or union link is broken, what should be done?

BROKEN COMBINATION LEVER

413. When the combination lever is broken what should be done?

BROKEN CROSS-HEAD

414. When a cross-head is broken so that it is necessary to remove the main rod, what should be done?

What different methods are sometimes used when disconnecting this valve gear?

TESTING FOR BLOWS WITH THE INSIDE ADMISSION PISTON VALVE

415. Explain in detail how to test for a valve blow, with the inside admission piston valve.

416. When the valve is central on its seat, and steam appears at either cylinder cock, what does it indicate?

If steam also blows through to the stack, what does it indicate?

When a continuous blow occurs at the stack, no steam showing at the cylinder cocks, what does it indicate?

TO TEST THE CYLINDER PACKING

417. In what position should the engine be placed to test for cylinder packing blows?

Explain in detail how to test for cylinder packing blows.

418. In what respect does the test for blows, with the outside admission piston, or balanced slide valve differ from that of the inside admission valve?

419. Are there any blows for which there is no absolutely sure test?

When these blows occur what should be done?

Name some of the blows for which there is no absolutely sure road test.

420. Is there any difference in the sound of a valve, or cylinder packing blow?

Is a cylinder packing blow continuous or intermittent?

When the engine is in the forward motion, when will the blow appear?

If in the back motion, when will the blow occur?

421. Is a valve blow continuous or intermittent?

POUNDS: HOW LOCATED

422. Explain how to test for pounds in the rods and cross-head.

How should the driving boxes and wedges be tested?

DRIVING BOX ADJUSTMENT

423. Explain how the driving axles are kept in tram or an equal distance apart.

What means is used to keep the pedestal jaws from wearing?

What means is used to take up the lost motion of the driving boxes?

Why is the adjustment of wedges a very important matter?

Why should the shoes be kept well oiled?

424. Explain how the driving box wedges should be adjusted.

If the wedges are set up too tight, what is liable to be the result?

THE THROTTLE VALVE COCKED OR DISCONNECTED

425. How may the throttle valve be closed when it becomes cocked, or is held open by scale?

426. What should be done when the throttle valve becomes disconnected?

427. After the steam pressure has been reduced, how may the throttle valve sometimes be closed?

If this means is not effective, what should be done?

428. Would it be good policy to try to handle a train with a locomotive having a disconnected throttle?

429. What is one of the most effective ways of reducing steam pressure in a boiler?

How may the movement of the engine be controlled?

430. If the throttle is closed when it becomes disconnected, what should be done?

SAND AND ITS USE

431. Why is sand used in connection with the movement of a locomotive?

432. Explain the different devices for applying sand to the rail.

433. Why must great care and good judgment be used in the use of sand?

434. Why is the hand lever sander not as satisfactory as other devices?

435. Is the use of sand over the movable parts of an interlocking plant prohibited?

436. Should sand be applied to the rail while an engine is slipping?

What might be the result if sand was applied to the rail while the engine was slipping?

THE MALLET ARTICULATING COMPOUND LOCOMOTIVE

437. In general construction, of what does the Mallet type of locomotive consist?

438. Are there more than one group of drivers?

439. Are the drivers all operated by the same cylinders?

440. On account of the long wheel base, what means is provided to allow the necessary flexibility?

441. Explain the manner in which the boiler is supported on the frames.

442. Why is the forward bearing fitted with controlling springs?

443. What is provided in the receiver pipe, connecting the high- and low-pressure cylinders, and the exhaust pipe connecting the low-pressure cylinders with the smoke box?

444. Give a general explanation of the boiler used with this locomotive.

445. How is water supplied to this boiler?

446. Is the feed water chamber provided with any safety device?

At what pressure is the safety valve set to open?

447. What means is provided for entering the combustion chamber?

448. What surrounds the combustion chamber?

449. Can the locomotive be separated into two sections?

450. What kind of a throttle valve is used with this locootive?

451. Explain the passage of the steam from the high o the low-pressure cylinders.

452. How is excess condensation in the low-pressure cylinders prevented?

453. Explain how the steam enters the reheater, and is conveyed to the low-pressure cylinders.

454. Are the low-pressure cylinders cast separately, or in one piece?

How are they fastened to the frames?

What means is provided for conducting the exhaust steam from the low-pressure cylinders to the atmosphere?

455. How are the joints in the exhaust pipe prevented from leaking?

456. What kind of valves are used?

457. How are the high-pressure cylinders lubricated?

458. How are the low-pressure cylinders lubricated?

459. What style of valve gear is used to operate the valves?

What lead is given the valves?

460. What means is provided for reversing the valve gear?

461. Explain in detail the operation of the ragonet power gear, as applied to the Mallet locomotive.

462. Explain how the forward and rear frames are connected.

463. How far do the front frames extend forward?

To what is the forward bumper beam attached?

What is the approximate maximum width of the cylinder casting?

464. How is the boiler supported on the front frames?

465. How is the wear taken off the forward boiler supports?

466. How are the frames prevented from falling away when the boiler is raised?

467. What kind of brake equipment is used?

468. What kind of compressors are used?

469. How are the cylinder cocks and sander operated?

470. To what are these engines practically equivalent?

471. What is necessary in order to develop full power when starting?

How may this be accomplished?

472. As soon as the engine is under way and the high-pressure cylinders are exhausting into the receiver pipe, what should be done?

473. In the event of a breakdown, how should this type of locomotive be handled?

474. In the event of cutting out one high-pressure cylinder only, what should be done?

475. Explain the difference between the Mallet locomotive, and two single-expansion locomotives coupled.

476. Explain the difference in the construction of the

boiler which enables it to take the place of, and do the work of two.

477. Give the general dimensions of the Mallet type class E-3 locomotive.

AIR BRAKES

478. What is a brake?

479. What is a hand brake?

480. What is a power brake?

481. Are the hand and power brakes ever combined?

482. What is an air brake?

483. Name the principal parts of the air brake system and explain their use.

THE WESTINGHOUSE AIR BRAKE SYSTEM

484. What is an air pump?

485. What is the air which it compresses used for?

486. How many systems of air brakes are there?

487. Explain the straight air system.

488. How are the straight air brakes released?

489. Explain the automatic system.

490. How are the automatic brakes released?

491. Is air admitted to or exhausted from the train line when applying the brakes with the straight air system?

492. Is air admitted to or exhausted from the train line when applying the brakes with the automatic system?

493. Are the straight and automatic systems ever combined on the engine and tender?

THE WESTINGHOUSE 9½-INCH AIR PUMP

494. Name the principal parts of the 9½-inch air pump.

495. Explain in detail the operation of the steam end of the 9½-inch air pump.

496. Explain the operation of the air end of the 9½-inch air pump.

WESTINGHOUSE 8½-INCH CROSS-COMPOUND COMPRESSOR

497. Explain the general construction of the Westinghouse 8½-inch cross-compound compressor.

498. Explain the operation of the steam end of the 8½-inch cross-compound compressor.

499. Explain the operation of the air end of the 8½-inch cross-compound compressor.

500. What is the relative capacity and consumption of steam of the 8½-inch cross-compound compressor and the 9½-inch pump?

AIR PUMP GOVERNOR

501. What is an air pump governor?

502. What designs of governors are generally used?

503. Where is the governor placed?

504. Name the piping connection of the single-top governor?

505. When the D-8 brake valve is used, what difference is there in the piping connections?

506. How is the single-top governor adjusted?

507. Explain the operation of the single-top governor in detail.

THE S-F AIR PUMP GOVERNOR

508. How many regulating heads has the S-F governor?

509. What is the reason for having two regulating heads on this governor?

510. At what pressure is the excess pressure head of the S-F governor adjusted to stop the pump?

511. At what pressure is the maximum pressure head of the S-F governor adjusted to stop the pump?

512. What is the difference between the maximum pressure head of S-F governor and the single-top governor?

513. What is the difference in the construction of the excess pressure head from that of the maximum pressure head of the S-F governor?

514. Explain the adjustment and operation of the excess pressure head of the S-F governor.

515. With what pressure is the maximum pressure head always in direct communication?

516. Explain the adjustment and operation of the maximum pressure head of the S-F governor.

517. What is the purpose of the small port in the steam valve?

518. What are the small vent ports in each governor head for? Why should one of these ports be plugged?

519. How should the excess pressure head of the S-F pump governor be adjusted?

520. How should the maximum pressure head of the S-F governor be adjusted?

ENGINEER'S BRAKE VALVES

521. What is the most simple device used for the control of compressed air on the locomotive?

522. Why is it called a three-way cock?

523. What does it do first? Second? Third?

524. When the handle is turned to the right, what occurs?

525. When the handle is turned to the left, what is the result?

THE COMBINED AUTOMATIC AND STRAIGHT AIR BRAKE

526. What is a combined automatic and straight air brake?

527. Where is the pressure taken from to operate the straight air brake when combined with the automatic system? What means are used to reduce the pressure supplied to the straight air valve?

To what pressure is the reducing valve adjusted?

528. Why is a double-seated check valve placed in the pipe connections of the combined automatic and straight air systems?

529. Explain the action of the double-seated check valve when the automatic valve is used.

530. When making either an automatic or straight air application of the brakes, will the double-seated check valve automatically adjust itself to the proper position?

531. Name the parts of the straight air portion of the combined automatic and straight air systems.

532. What is the safety or pressure reducing valve used for?

AUTOMATIC BRAKE VALVES

533. How many valves does the automatic brake valve contain?

534. What is the first valve and its use?

535. What is the second valve and its use?

536. Name the third valve, and explain its use?

537. How should the brake valve handle be operated to make an ordinary stop?

538. If it is desired to make a further application of the brakes, after returning the brake handle to lap position, how should it be done?

If it is desired to release the brakes, how should it be done?

539. How should the brake valve be operated to apply the brakes in the emergency position?

540. What pressures are combined in the brake cylinders when the emergency position is used?

541. As the train line and auxiliary pressures are the same, how is a higher pressure obtained in the brake cylinders by an emergency application than can be obtained by a service application of the brakes?

542. How does the air feed through the brake valve when in full release position?

543. How does the air pass to the train pipe when the brake valve is in running position?

THE G–6 TYPE OF ENGINEER'S AUTOMATIC BRAKE VALVE, RELEASE POSITION

544. Explain in detail the flow of air through the G-6 brake valve, in release position?

RUNNING POSITION, G–6 TYPE

545. Trace the air through the G-6 brake valve, in running position.

SERVICE APPLICATION POSITION, G–6 TYPE

546. Explain the movement of the valve, and trace the air through it in service application position.

LAP POSITION, G–6 TYPE

547. What occurs when the brake valve is placed on lap position?

EMERGENCY POSITION, G–6 TYPE

548. Explain the flow of air through the brake valve, in the emergency position?

THE E T LOCOMOTIVE BRAKE EQUIPMENT

549. When was the Westinghouse E T locomotive brake equipment first introduced?

550. How are the two designs of the E T equipment now in use designated?

551. What is the only difference in manipulation between the No. 5 and the No. 6 equipment?

552. What is one of the advantages of this equipment?

553. Has the automatic brake valve used with the E T equipment any more ports than the G-6 style? Where is this holding position placed?

What is the holding position used for?

554. How is the holding action accomplished?

555. What does the distributing valve and double chamber reservoir take the place of?

556. With the E T equipment, through what are the independent and automatic brakes united?

557. When the brakes are applied automatically, can they be released or applied on the locomotive by the independent brake valve?

558. How may the independent brake valve be used to advantage on long grades?

559. When the brakes are applied by the independent brake valve, by what means is the leakage overcome and the pressure maintained in the brake cylinder, until released by the independent brake valve?

560. Why is this maintaining feature a very important safety device?

561. What is the independent brake valve not intended to be used for?

PIPING OF THE NO. 6 E T EQUIPMENT

562. Beginning at the discharge from the air pump, trace the air to the brake valve. Why is a cut-out cock

placed in the main reservoir pipe? What is placed in the end of this cut-out cock, next to the main reservoir?

563. When necessary to close the main reservoir cut-out cock, what other cut-out cock should first be closed?

564. Beyond the main reservoir cut-out cock how many branches has the main reservoir pipe?

565. In how many ways does the automatic brake valve receive air from the main reservoir?

566. To what is the branch of the feed valve pipe connected?

567. To what is the third branch of the main reservoir pipe connected? By what means is the pressure reduced and supplied to the independent brake valve?

568. When the air signal system is installed, to what is it connected?

569. What is placed in the branch pipe supplying the air signal system?

570. What does the choke fitting in the signal branch pipe prevent?

571. Explain the piping of the distributing valve.

572. What is placed in the brake cylinder pipes?

573. To what pipe is the red hand in gauge No. 1 connected?

574. To what is the black hand in gauge No. 1 connected?

575. In gauge No. 2, to what is the red hand connected? To what is the black hand connected?

576. What gauge and hand registers the amount of reduction made during an automatic application of the brakes?

577. What is the black hand of gauge No. 2 used for?

578. What are the brake valve connections other than those already mentioned?

THE DEAD ENGINE FEATURE

579. Explain in detail the dead engine feature as provided in the piping of the E T equipment. When the dead engine feature is not in use how is it cut out?

THE DISTRIBUTING VALVE AND DOUBLE CHAMBER RESERVOIR

580. Of how many portions does the distributing valve consist?

581. To what is the distributing valve connected? Of the two chambers of the double chamber reservoir, what is the larger one? The small one?

582. To what portion of the distributing valve is the application chamber connected and for what purpose?

583. When are the equalizing portion and pressure chamber used?

584. When a reduction of brake pipe pressure occurs, what does the resulting movement of the equalizing valve connect?

585. What work does the upper slide valve connected to the piston rod of the application portion perform? What is this valve called?

What work does the lower valve perform? What is it called?

586. Where does the air come from that is admitted to the brake cylinders by the application valve?

587. How many pipes are connected to the distributing valve? Why are the piping connections made to the reservoir body direct?

588. What is the purpose of the connection marked M. R.?

589. What work does themiddle one marked 2 perform?

590. What is the lower left-hand pipe, marked 4?

591. Of the two pipes on the right, what is the upper one marked C.Y.L.S.?

592. What is the lower pipe on the right, marked B. P.?

593. Name the different parts of the distributing valve and double chamber reservoir.

AUTOMATIC OPERATION OF THE DISTRIBUTING VALVE, CHARGING POSITION

594. Explain the flow of air in the distributing valve in charging position.

AUTOMATIC SERVICE

595. Give a detailed explanation of the action of the distributing valve and the passage of air through it, in automatic service position.

SERVICE LAP

596. Explain the position of the valve and the passage of air through it, to produce service lap?

AUTOMATIC RELEASE

597. Describe the position of the valve and the flow of air through it, in automatic release position.

EMERGENCY

598. Explain the movement of the distributing valve and the flow of air through it, in emergency application.

EMERGENCY LAP

599. Explain the action of the distributing valve and the flow of air through it, to produce emergency lap.

600. What occurs in the distributing valve when the automatic brake valve handle is moved to release position, following an emergency application?

601. What movement takes place in the distributing valve when the brakes are applied by a burst hose, train parting, or conductor's valve?

When the brakes are applied in this manner, where should the handle of the automatic brake valve be placed? Why?

INDEPENDENT BRAKE OPERATION

602. Does the equalizing portion of the distributing valve move when the brakes are applied or released with the independent brake valve?

603. Explain what takes place when the handle of the independent brake valve is moved to application position.

INDEPENDENT RELEASE

604. What occurs when the handle of the independent brake valve is moved to release position?

605. Can the brakes on the locomotive and tender be released independently when automatically applied?

606. What is necessary to release the locomotive brakes independently, after an emergency application of the brakes by the automatic brake valve?

THE QUICK-ACTION CYLINDER CAP

607. What is the quick-action cylinder cap used for?

608. Name the parts of the quick-action cylinder cap.

609. Explain the action of the distributing valve in emergency application, with the quick-action cylinder cap attachment.

610. When an emergency application of the brakes is made, how is brake cylinder pressure prevented from flowing back to the brake pipe?

611. How is the distributing valve drained of any moisture which may gather in it?

612. When it is desired to remove piston 10 or slide valve 16, what is first absolutely necessary?

THE H-6 ENGINEER'S BRAKE VALVE

613. Does the H-6 brake valve differ from other styles of brake valves?

614. Why is this difference in construction necessary?

615. How many positions has the H-6 brake valve? Name them, beginning at the left?

616. Name the different parts of the brake valve.

ROTARY VALVE, H-6 AUTOMATIC BRAKE VALVE

617. Explain the arrangement of ports, passages, and cavities of the rotary valve.

618. Explain the arrangement of ports in the rotary valve seat.

CHARGING AND RELEASE POSITION

619. Explain the flow of air when the H-6 brake valve is in charging and release positions.

620. If the brake valve handle is allowed to remain for too long a time in release and charging position, what will occur? To avoid overcharging the train pipe, to what position must the brake valve handle be moved?

621. While in charging position, is main reservoir pressure connected with the pump governor through the brake valve?

622. Will the release or charging position of the H-6 automatic brake valve release the locomotive brakes, if they are applied?

RUNNING POSITION

623. When must the brake valve be carried in running position?

624. Explain the flow of air through the brake valve when in running position.

625. Where do ports *S* in the rotary and *P* in the seat permit air at main reservoir pressure to flow?

626. What ports in the rotary valve and its seat connect the distributing valve release pipe with the exhaust port *Ex?*

627. What causes the pump to stop when uncharged cars are cut in?

628. What should be done when coupling the locomotive to a train?

After the air has been turned into the brake pipe, in what position should the brake valve handle be placed?

SERVICE POSITION

629. How should a service application of the brakes be made?

630. Why is it necessary to have the preliminary exhaust port restricted to a certain size?

631. Explain the flow of air through the brake valve in service position.

632. What is the result of a reduction of pressure in chamber *D* and the equalizing reservoir?

633. When a sufficient reduction of pressure has been made in chamber *D* and the equalizing reservoir, where must the brake valve handle be placed?

634. Explain how the flow of brake pipe air to the atmosphere is stopped.

635. When a service application of the brakes is made, is there any difference in the pressure exhausted per square inch in chamber *D*, the equalizing reservoir and the brake pipe?

636. What determines the reduction of brake pipe pressure regardless of the length of the train?

LAP POSITION

637. Are all ports covered when the brake valve handle is on lap position?

638. What is lap position used for?

HOLDING POSITION

639. What is the most important feature of the H-6 brake valve in its connection with the distributing valve?

640. What position of the brake valve handle will release train brakes and retain the engine and tender brakes?

641. Explain what controls the brake pipe pressure and why the engine brakes do not release when the brake valve handle is placed in holding position.

642. What is the difference between running and holding positions?

643. When the locomotive brakes have been held applied by means of holding position, how may they be released?

644. How may the locomotive brakes be graduated off?

EMERGENCY POSITION

645. How should an emergency application of the brakes be made?

When should the emergency position be used?

646. Explain how the ports in the brake valve register in the emergency position.

647. What causes the triple valves on the train to move to emergency position?

648. When the brake valve is in emergency position, how does it affect the action of the distributing valve?

649. What is the purpose of oil plug 29?

THE S-6 INDEPENDENT BRAKE VALVE

650. In connection with what is the S-6 independent brake valve used?

651. How many positions has the S-6 independent brake valve?

652. Name the different parts of the S-6 independent brake valve.

653. Explain the arrangement of ports in the rotary valve and seat.

RUNNING POSITION

654. Explain the S-6 independent brake valve and its arrangement of ports in running position.

SLOW APPLICATION POSITION

655. Explain the S-6 independent brake and its arrangement of ports in slow application position.

QUICK APPLICATION POSITION

656. Explain the arrangements of ports and the flow of air through them in quick service application of the S-6 brake valve.

LAP POSITION

657. Explain what takes place when the independent brake valve handle is placed on lap position, after an application of the brakes.

RELEASE POSITION

658. When is the release position of the S-6 independent brake valve necessary?

659. What is the purpose of return spring 6?

660. If the return spring 6 becomes broken, allowing the valve to go to release position, what would warn the engineer?

661. For what purpose is plug 20 provided?

THE B-6 FEED VALVE

662. Why is the B-6 feed valve considered an improvement over other valves?

663. To what pressure is this valve directly connected? What pressure does it control?

664. Name the different parts of the B-6 feed valve.

665. How many operative parts has the B-6 feed valve? Of what does the supply part consist? Of what does the regulating part consist?

666. Explain in detail the operation of the B-6 feed valve.

667. How may the pressures be changed from high- to low-, or low- to high-pressure with this feed valve?

668. Why is it not necessary to adjust the pump governor when changing the feed valve pressure?

DOUBLE HEADING

669. When double heading, which engine should control the brakes?

What precaution is necessary?

670. What should be done, when double heading with an engine equipped with a G-6 brake valve?

671. What should be done when double heading with an engine equipped with an H-5 brake valve?

672. What should be done when double heading with an engine equipped with an H-6 brake valve?

673. How may the H-5 and H-6 brake valves be distinguished from each other?

TRIPLE VALVES, THE QUICK ACTION TRIPLE VALVE

674. How many operative parts has the quick-action triple valve and when are they operative?

675. Of what does the service application part consist?

676. Of what does the emergency part consist?

CHARGING POSITION

677. Explain the action of the valve and the flow of air through it, in charging position.

SERVICE APPLICATION

678. Explain the action of the quick-action triple valve, in service application.

679. When two or more reductions of pressure are made

without releasing the brakes, does the slide valve move with each application?

LAP POSITION

680. Explain the purpose of lap position.

RELEASE POSITION

681. Give a detailed explanation of the action of the triple valve, when the brake valve handle is placed in release position after an application of the brakes.

EMERGENCY POSITION

682. What may be the cause of the triple valve moving to emergency position?

683. Give a detailed explanation of the action of the valve and arrangement of ports, in emergency application.

684. What is the effect of uniting the auxiliary and brake pipe pressures in emergency application?

THE K–2 TRIPLE VALVE

685. Is there any difference in the manner of handling the brake valve, with the K-2 triple, than with the old-style quick-action triple?

686. How many positions has the K-2 triple valve?

687. What is the first of the advantages claimed for the K-2 triple valve?

688. Does air from both the brake pipe and auxiliary reservoir enter the brake cylinder in quick service application of the brakes?

689. What is the second advantage claimed for the K-2 triple valve?

690. What is the third important feature of this valve?

691. Explain how the low pressure in the rear end of the brake pipe can recharge the auxiliary reservoirs on the rear end of the train as quickly as the high pressure in the head end of the brake pipe can recharge the auxiliaries on the head end of the train.

THE AIR SIGNAL SYSTEM

692. For what purpose is the air signal system used?

693. In general construction, of what does the signal system consist?

694. From what does the signal pipe get its supply of air and what controls its pressure?

695. Is there any difference between the reducing valve used with the signal system and the reducing valve used with the independent brake valve?

696. To what does the connection in the signal pipe lead?

THE AIR WHISTLE SIGNAL VALVE

697. What does the whistle signal valve control?

698. How many operative parts does the whistle valve contain?

699. Give a detailed explanation of the operation of the air whistle signal valve.

700. When the whistle is to be sounded, how should the conductor's valve be operated to secure the best results?

701. If the whistle cord is pulled for a series of signals and a sufficient length of time is not allowed to elapse between the pulls, what will be the result?

702. Will a leak in the signal line cause the valve to operate and the whistle to sound?

703. If the whistle does not respond when the conductor's signal valve is opened, what may be the cause?

PRESSURE RETAINING VALVES

704. What are pressure retaining valves used for?

705. In what way does the use of retaining valves add to the safety of handling trains?

706. Explain the general construction of a retaining valve.

707. Where is the retaining valve usually placed and to what is it connected?

708. How should the retaining valve be operated?

709. What pressure is retained by the ordinary retaining valve?

710. Explain the construction and operation of the new three-position retaining valve?

711. When the handle is in line with the pipe will the valve retain any pressure?

712. What pressure does the valve retain when the handle is placed at an angle of 45 degrees?

713. What pressure does the valve retain when the handle is placed in a horizontal position at right angles to the pipe?

FACTS TO BE REMEMBERED IN THE OPERATION OF THE AUTOMATIC BRAKE SYSTEM

714. What attention should the engineer give to the locomotive brake equipment before leaving the engine house?

715. What attention should be given the air compressors and governors?

716. What test should be given the brake valve and air gauges?

717. Explain how the brakes should be operated when coupling to a train, to insure a quick and uniform release and a quick recharge.

TESTING TRAIN BRAKES

718. When testing the operation of train brakes, how much should the brake pipe pressure be reduced?

719. What is required of the inspectors after the brakes have been applied by the engineer's brake valve?

720. After inspecting the brakes and signaling the engineer to release brakes, what is required of the inspectors?

721. If the equipment is found defective or the brakes do not apply, what must be done?

APPLYING THE BRAKES

722. How should the brakes be applied on long freight trains, to make a service stop?

723. Upon what does the first reduction of brake pipe pressure depend when braking passenger trains?

RELEASING THE BRAKES

724. Why should the brakes not be released when an emergency application of the brakes has been made, until the train has come to a full stop?

725. What is another good reason for not releasing the brakes after an emergency application, until the train has come to a full stop?

726. Upon what will the manner of release depend, when making a running release after a service application of the brakes?

727. Under what conditions would it not be safe to release at a speed of less than twelve miles per hour? Under what conditions may the brakes be safely released, at a less rate of speed?

728. On passenger trains when making station stops, why should the brakes be released immediately before the train comes to a full stop?

729. How should the brakes be applied on passenger trains, when running around curves at a high rate of speed?

730. With trains of eight cars or more, how much of a reduction should be made?

731. What may be the result if a less reduction is made?

DISORDERS OF THE AIR BRAKE EQUIPMENT AND THEIR REMEDIES

732. To what causes may the disorders and defects of the air brake usually be attributed?

733. How may air leaks in the piping usually be remedied?

734. What is the most usual cause of leaky operative parts?

735. How may defects in the operation of the brake, caused by dirty or gummed parts, be remedied?

736. Of what are broken piping or operative parts usually the result? Why do defects arising from this source usually require a thorough knowledge of the equipment?

737. If the feed valve pressure pipe, leading to the top of the excess pressure head of the pump governor, is broken, what must be done?

738. If the main reservoir pressure pipe connection to the maximum pressure head of the pump governor, is broken off, what should be done?

739. If the governor heads are both inoperative, how may the pump be controlled?

740. Can the brakes be operated when the pipe connection between the equalizing reservoir and the brake valve is broken?

741. If the equalizing reservoir or pipe connection is broken, what should be done?

742. Can the brakes be operated with the gauge pipes broken?

743. Can the brakes be operated when any of the brake cylinder branch pipes are broken?

744. If any of the branch pipe connections to the brake pipe are broken, what should be done?

745. When it becomes necessary to plug a tee connection to the main reservoir pipe or brake pipe, what care must be exercised?

746. If the main reservoir branch pipe connection to

the distributing valve is broken off, what should be done? What will be the result?

747. If the application cylinder pipe is broken off, what should be done? What will be the result?

748. What would be the result if the distributing valve release pipe is broken?

749. If the brake valve cylinder pipe is broken off, what will be the result and what should be done?

750. If the brake pipe branch connection to the distributing valve is broken off, what should be done?

751. When the brake pipe branch connection to the distributing valve is broken off, can the brakes be applied on the locomotive?

752. When a bad leak is apparent by the action of the pump, how may its location be determined?

753. What will be the result if the rotary valve of the automatic brake valve leaks badly?

754. How may the rotary valve be tested for leaks?

755. If a bad leak should appear in the auxiliary reservoir, triple valve, or brake cylinder, what should be done?

756. When a leak or break occurs between the cut-out cock and the main brake pipe, how may it be repaired?

757. Explain how a leak or break in the brake pipe may be repaired in another way?

758. If the brake pipe on a passenger car is broken, how may the car be retained in the train and the brakes operated on the cars behind it?

759. How may a leak in the rotary valve of the independent brake valve, be detected?

760. If the rotary valve of the independent brake valve

is leaking and a partial service application is made with either valve and returned to lap, what will be the result?

761. When a partial automatic service application is made and the brake valve returned to lap position, what will be the result of any leakage in the brake pipe, equalizing slide valve, graduating valve, or the independent rotary valve?

762. If a continuous blow occurs at the brake cylinder exhaust port of the distributing valve, what is leaking?

763. When either brake valve is placed on lap after a service application, what will be the result of any leakage from the application cylinder of the distributing valve?

764. What will be the result of failure to operate the brakes, according to prescribed rules and such failures result in delays, or serious consequences?

765. With whom does the remedy for this condition lay?

EXTRACTS FROM STANDARD RULES, GENERAL DEFINITIONS

766. What is a train?

767. What is a regular train?

768. What is a section?

769. What are extra trains?

770. What is a work train extra?

771. What are passenger train extras?

772. What is a superior train?

773. What is a train of superior right?

774. What is a train of superior class?

775. What is a train of superior direction?

776. What is a time-table?
777. What does a time-table contain?
778. What is a schedule?
779. What is a division?
780. What is a main track?
781. What is a siding?
782. What is a single-track system?
783. What is a double-track system?
784. What are three or more tracks?
785. What is a station?
786. What is a yard?
787. What is a pilot?

SIGNAL DEFINITIONS

788. What is a block?
789. What is a block station?
790. What is a block signal?
791. What is a home block signal?
792. What is a distant block signal?
793. What is an advance block signal?
794. What is a block system?
795. What is a manual block system?
796. What is a controlled manual block system?
797. What is an automatic block system?

INTERLOCKING SIGNALS

798. What is an interlocking?
799. What is an interlocking plant?
800. What is an interlocking station?

801. What are interlocking signals?
802. What are home interlocking signals?
803. What are distant interlocking signals?
804. What is a dwarf interlocking signal?

THE TIME-TABLE

805. What is shown on the face of each time-table?

806. How many times may be shown for one train at any point?

807. Where only one time is shown, what is it?

808. Where two times are shown, what are they?

809. Are trains allowed to arrive ahead of their arriving time, or leave ahead of their leaving time?

810. Where trains are scheduled to meet at any point, the time for the train at that point is shown in what kind of type?

811. What kind of type is used to show the number of the trains to be met or passed?

812. To the left of the list of station names what is shown?

813. What are the small figures shown between the names of the stations?

814. When the letter S is shown before the time of a train at stations, what does it indicate?

815. What does the letter F indicate, when shown before the time of trains at certain stations?

816. What does the letter D stand for? The letter N, D and N?

817. Other small letters are shown for certain trains

at designated stations. What do these letters refer to?

818. Where on each time-table is shown the number of the time-table? The date and hour it takes effect?

819. How are trains designated?

820. Are extras listed on the schedule?

821. To what is a first-class train superior?

822. To what is a second-class train superior?

823. Do extra trains have right or class?

TRAIN PROTECTION

824. When an accident occurs to a train what protection must be given other trains at once?

825. When a train stops or becomes delayed so that it may be overtaken by other trains, what is required of the flag-man at once?

826. How must the front end of the train be protected, when necessary?

827. How must trains approach the end of double track, junctions, railroad crossings at grade and drawbridges?

828. Where required by law, what must trains do?

829. Who are held responsible for the safe movement of their trains?

830. Why can no hard and fast rule be applied to conditions on all roads?

THE LOCOMOTIVE ENGINEER

831. Give a general description of the duties and requirements of a locomotive engineer?

ECONOMICAL OPERATION

832. What knowledge of the physical conditions of the road is necessary to the economical handling of trains?

833. Describe how a train should be started and how the engine should be operated, to give the best results both at high and low rates of speed?

834. By what means may energy be wasted?

835. How may supplies be wasted?

836. What should every engineer practise, in the use of supplies and the running of his engine?

PERSONAL INJURIES

837. Why is it necessary for each engineer to know something of emergency treatment of the injured?

838. If a leg is cut off, what should be done to stop the flow of blood?

839. If the flesh is torn or cut and the parts not severed, what should be done?

840. If an artery is severed, how may the flow of blood be stopped?

841. If a vein is severed, how should it be treated?

842. How can the arterial blood be distinguished from venous blood?

843. Why is it necessary to place the binder in different places to stop the bleeding, when an artery is severed and when a vein is severed?

844. If a leg or arm is broken, how should it be treated?

845. In case of scalds or burns, what should be done?

846. If the injured person becomes unconscious, what means may be used to restore consciousness?

847. In case of a fall or electric shock, what should be done?

848. If the injury is about the body so that the foregoing rules cannot be observed what should be done?

DEPORTMENT

849. What should every engineer endeavor to maintain?

850. Why should an engineer always treat his fireman in a courteous manner?

851. What can be gained by co-operation?

INDEX

CATALOGUE OF STANDARD PRACTICAL AND SCIENTIFIC BOOKS

PUBLISHED AND FOR SALE BY

The Norman W. Henley Publishing Co.

132 Nassau St., New York, U. S. A.

INDEX OF SUBJECTS

☞ **Any of these books will be sent prepaid to any part of the world, on receipt of price.**

REMIT by Draft, Postal Money Order, Express Money Order or by Registered Mail.

GOOD, USEFUL BOOKS

BRAZING AND SOLDERING

BRAZING AND SOLDERING. By James F. Hobart. The only book that shows you just how to handle any job of brazing or soldering that comes along; tells you what mixture to use, how to make a furnace if you need one. Full of kinks. 4th edition. **25 cents**

CHARTS

BATTLESHIP CHART. An engraving which shows the details of a battleship as if the sides were of glass and you could see all the interior. The finest piece of work that has ever been done. So accurate that it is used at Annapolis for instruction purposes. Shows all details and gives correct name of every part. 28 x 42 inches—plate paper. **50 cents**

BOX CAR CHART. A chart showing the anatomy of a box car, having every part of the car numbered and its proper name given in a reference list. **20 cents**

GONDOLA CAR CHART. A chart showing the anatomy of a gondola car, having every part of the car numbered and its proper reference name given in a reference list. **20 cents**

PASSENGER CAR CHART. A chart showing the anatomy of a passenger car, having every part of the car numbered and its proper name given in a reference list. **20 cents**

TRACTIVE POWER CHART. A chart whereby you can find the tractive power or drawbar pull of any locomotive, without making a figure. Shows what cylinders are equal, how driving wheels and steam pressure affect the power. What sized engine you need to exert a given drawbar pull or anything you desire in this line. **50 cents**

WESTINGHOUSE AIR-BRAKE CHARTS. Chart I.—Shows (in colors) the most modern Westinghouse High Speed and Signal Equipment used on Passenger Engines, Passenger Engine Tenders, and Passenger Cars. Chart II.—Shows (in colors) the Standard Westinghouse Equipment for Freight and Switch Engines, Freight and Switch Engine Tenders, and Freight Cars. Price for the set, **50 cents**

CHEMISTRY

HENLEY'S TWENTIETH CENTURY BOOK OF RECEIPTS, FORMULAS AND PROCESSES. Edited by Gardner D. Hiscox. The most valuable Techno-chemical Receipt Book published, including over 10,000 selected scientific chemical, technological, and practical receipts and processes. **See page 24 for full description of this book.** **$3.00**

CIVIL ENGINEERING

HENLEY'S ENCYCLOPEDIA OF PRACTICAL ENGINEERING AND ALLIED TRADES. Edited by Joseph G. Horner, A.M.I., M.E. This set of five volumes contains about 2,500 pages with thousands of illustrations, including diagrammatic and sectional drawings with full explanatory details. It covers the entire practice of Civil and Mechanical Engineering. It tells you all you want to know about engineering and tells it so simply, so clearly, so concisely that one cannot help but understand. **$6.00** per volume or **$25.00** for complete set of five volumes.

COKE

COKE—MODERN COKING PRACTICE; INCLUDING THE ANALYSIS OF MATERIALS AND PRODUCTS. By T. H. Byrom, Fellow of the Institute of Chemistry, Fellow of The Chemical Society, etc., and J. E. Christopher, Member of the Society of Chemical Industry, etc. A handbook for those engaged in Coke manufacture and the recovery of By-products. Fully illustrated with folding plates.

The subject of Coke Manufacture is of rapidly increasing interest and significance, embracing as it does the recovery of valuable by-products in which scientific control is of the first importance. It has been the aim of the authors, in preparing this book, to produce one which shall be of use and benefit to those who are associated with, or interested in, the modern developments of the industry.

Contents: Chap. I. Introductory. Chap. II. General Classification of Fuels. Chap. III. Coal Washing. Chap. IV. The Sampling and Valuation of Coal, Coke, etc. Chap. V. The Calorific Power of Coal and Coke. Chap. VI. Coke Ovens. Chap. VII. Coke Ovens, continued. Chap. VIII. Coke Ovens, continued. Chap. IX. Charging and Discharging of Coke Ovens. Chap. X. Cooling and Condensing Plant. Chap. XI. Gas Exhausters. Chap. XII. Composition and Analysis of Ammoniacal Liquor. Chap. XIII. Working up of Ammoniacal Liquor. Chap. XIV. Treatment of Waste Gases from Sulphate Plants. Chap. XV. Valuation of Ammonium Sulphate. Chap. XVI. Direct Recovery of Ammonia from Coke Oven Gases. Chap. XVII. Surplus Gas from Coke Oven. Useful Tables. Very fully illustrated. **$3.50 net**

COMPRESSED AIR

COMPRESSED AIR IN ALL ITS APPLICATIONS By Gardner D. Hiscox. This is the most complete book on the subject of Air that has ever been issued, and its thirty-five chapters include about every phase of the subject one can think of. It may be called an encyclopedia of compressed air. It is written by an expert, who, in its 665 pages, has dealt with the subject in a comprehensive manner, no phase of it being omitted. Over 500 illustrations, 5th Edition, revised and enlarged. Cloth bound; **$5.00,** Half morocco, **$6.50**

CONCRETE

ORNAMENTAL CONCRETE WITHOUT MOLDS, By A. A. HOUGHTON. The process for making ornamental concrete without molds, has long been held as a secret and now, for the first time, this process is given to the public. The book reveals the secret and is the only book published which explains a simple, practical method whereby the concrete worker is enabled, by employing wood and metal templates of different designs, to mold or model in concrete any Cornice, Archivolt, Column, Pedestal, Base Cap, Urn or Pier in a monolithic form—right upon the job. These may be molded in units or blocks, and then built up to suit the specifications demanded. This work is fully illustrated, with detailed engravings. **$2.00**

POPULAR HAND BOOK FOR CEMENT AND CONCRETE USERS, By MYRON H. LEWIS, C.E. This is a concise treatise of the principles and methods employed in the manufacture and use of cement in all classes of modern works. The author has brought together in this work, all the salient matter of interest to the user of concrete and its many diversified products. The matter is presented in logical and systematic order, clearly written, fully illustrated and free from involved mathematics. Everything of value to the concrete user is given. Among the chapters contained in the book are: I. Historical Development of the Uses of Cement and Concrete. II. Glossary of Terms employed in Cement and Concrete work. III. Kinds of Cement employed in Construction. IV. Limes, Ordinary and Hydraulic. V. Lime Plasters. VI. Natural Cements. VII. Portland Cements. VIII. Inspection and Testing. IX. Adulteration; or Foreign Substances in Cement. X. Sand, Gravel and Broken Stone. XI. Mortar. XII. Grout. XIII. Concrete (Plain). XIV. Concrete (Reinforced). XV. Methods and Kinds of Reinforcements. XVI. Forms for Plain and Reinforced Concrete. XVII. Concrete Blocks. XVIII. Artificial Stone. XIX. Concrete Tiles. XX. Concrete Pipes and Conduits. XXI. Concrete Piles. XXII. Concrete Buildings. XXIII. Concrete in Water Works. XXIV. Concrete in Sewer Works. XXV. Concrete in Highway Construction. XXVI. Concrete Retaining Walls. XXVII. Concrete Arches and Abutments. XXVIII. Concrete in Subway and Tunnels. XXIX. Concrete in Bridge Work. XXX. Concrete in Docks and Wharves. XXXI. Concrete Construction under Water. XXXII. Concrete on the Farm. XXXIII. Concrete Chimneys. XXXIV. Concrete for Ornamentation. XXXV. Concrete Mausoleums and Miscellaneous Uses. XXXVI. Inspection for Concrete Work. XXXVII. Waterproofing Concrete Work. XXXVIII. Coloring and Painting Concrete Work. XXXIX. Method of Finishing Concrete Surfaces. XL. Specifications and Estimates for Concrete Work. **$2.50**

DICTIONARIES

STANDARD ELECTRICAL DICTIONARY. By T. O'CONOR SLOANE. An indispensable work to all interested in electrical science. Suitable alike for the student and professional. A practical hand-book of reference containing definitions of about 5,000 distinct words, terms and phrases. The definitions are terse and concise and include every term used in electrical science. Recently issued. An entirely new edition. Should be in the possession of all who desire to keep abreast with the progress of this branch of science. Complete, concise and convenient. 682 pages—393 illustrations. **$3.00**

DIES—METAL WORK

DIES, THEIR CONSTRUCTION AND USE FOR THE MODERN WORKING OF SHEET METALS. By J. V. Woodworth. A new book by a practical man, for those who wish to know the latest practice in the working of sheet metals. It shows how dies are designed, made and used, and those who are engaged in this line of work can secure many valuable suggestions. **$3.00**

PUNCHES, DIES AND TOOLS FOR MANUFACTURING IN PRESSES. By J. V. Woodworth. An encyclopedia of die-making, punch-making, die-sinking, sheet-metal working, and making of special tools, subpresses, devices and mechanical combinations for punching, cutting, bending, forming, piercing, drawing, compressing, and assembling sheet-metal parts and also articles of other materials in machine tools. This is a distinct work from the author's book entitled "Dies; Their Construction and Use." 500 pages, 700 engravings. **$4.00**

DRAWING—SKETCHING PAPER

LINEAR PERSPECTIVE SELF-TAUGHT. By Herman T. C. Kraus. This work gives the theory and practice of linear perspective, as used in architectural, engineering, and mechanical drawings. Persons taking up the study of the subject by themselves, without the aid of a teacher, will be able by the use of the instruction given to readily grasp the subject, and by reasonable practice become good perspective draftsmen. The arrangement of the book is good; the plate is on the left-hand, while the descriptive text follows on the opposite page, so as to be readily referred to. The drawings are on sufficiently large scale to show the work clearly and are plainly figured. The whole work makes a very complete course on perspective drawing, and will be found of great value to architects, civil and mechanical engineers, patent attorneys, art designers, engravers, and draftsmen. **$2.50**

PRACTICAL PERSPECTIVE. By Richards and Colvin. Shows just how to make all kinds of mechanical drawings in the only practical perspective isometric. Makes everything plain so that any mechanic can understand a sketch or drawing in this way. Saves time in the drawing room and mistakes in the shops. Contains practical examples of various classes of work. **50 cents**

SELF-TAUGHT MECHANICAL DRAWING AND ELEMENTARY MACHINE DESIGN. By F. L. Sylvester, M.E., Draftsman, with additions by Erik Oberg, associate editor of "Machinery." A practical elementary treatise on Mechanical Drawing and Machine Design, comprising the first principles of geometric and mechanical drawing, workshop mathematics, mechanics, strength of materials and the calculation and design of machine details, compiled for the use of practical mechanics and young draftsmen. **$2.00**

A NEW SKETCHING PAPER. A new specially ruled paper to enable you to make sketches or drawings in isometric perspective without any figuring or fussing. It is being used for shop details as well as for assembly drawings, as it makes one sketch do the work of three, and no workman can help seeing just what is wanted. Pads of 40 sheets, 6 x 9 inches, **25 cents.** Pads of 40 sheets, 9 x 12 inches, **50 cents**

ARITHMETIC OF ELECTRICITY. By Prof. T. O'Conor Sloane. A practical treatise on electrical calculations of all kinds reduced to a series of rules, all of the simplest forms, and involving only ordinary arithmetic; each rule illustrated by one or more practical problems, with detailed solution of each one. This book is classed among the most useful works published on the science of electricity covering as it does the mathematics of electricity in a manner that will attract the attention of those who are not familiar with algebraical formulas. 160 pages. **$1.00**

COMMUTATOR CONSTRUCTION. By Wm. Baxter, Jr. The business end of any dynamo or motor of the direct current type is the commutator. This book goes into the designing, building, and maintenance of commutators, shows how to locate troubles and how to remedy them; everyone who fusses with dynamos needs this. **25 cents**

DYNAMO BUILDING FOR AMATEURS, OR HOW TO CONSTRUCT A FIFTY WATT DYNAMO. By Arthur J. Weed, Member of N. Y. Electrical Society. This book is a practical treatise showing in detail the construction of a small dynamo or motor, the entire machine work of which can be done on a small foot lathe.

Dimensioned working drawings are given for each piece of machine work and each operation is clearly described.

This machine when used as a dynamo has an output of fifty watts; when used as a motor it will drive a small drill press or lathe. It can be used to drive a sewing machine on any and all ordinary work.

The book is illustrated with more than sixty original engravings showing the actual construction of the different parts. Paper.
Paper **50 cents** Cloth **$1.00**

ELECTRIC FURNACES AND THEIR INDUSTRIAL APPLICATIONS. By J. Wright. This is a book which will prove of interest to many classes of people; the manufacturer who desires to know what product can be manufactured successfully in the electric furnace, the chemist who wishes to post himself on the electro-chemistry, and the student of science who merely looks into the subject from curiosity. 288 pages. **$3.00**

ELECTRIC LIGHTING AND HEATING POCKET BOOK. By Sydney F. Walker. This book puts in convenient form useful information regarding the apparatus which is likely to be attached to the mains of an electrical company. Tables of units and equivalents are included and useful electrical laws and formulas are stated. 438 pages, 300 engravings. **$3.00**

ELECTRIC TOY MAKING, DYNAMO BUILDING, AND ELECTRIC MOTOR CONSTRUCTION. This work treats of the making at home of electrical toys, electrical apparatus, motors, dynamos, and instruments in general, and is designed to bring within the reach of young and old the manufacture of genuine and useful electrical appliances. 185 pages. Fully illustrated. **$1.00**

ELECTRIC WIRING, DIAGRAMS AND SWITCH-BOARDS. By NEWTON HARRISON. This is the only complete work issued showing and telling you what you should know about direct and alternating current wiring. It is a ready reference. The work is free from advanced technicalities and mathematics. Arithmetic being used throughout. It is in every respect a handy, well-written, instructive, comprehensive volume on wiring for the wireman, foreman, contractor or electrician. 272 pages, 105 illustrations. **$1.50**

ELECTRICIAN'S HANDY BOOK. By PROF. T. O'CONOR SLOANE. This work is intended for the practical electrician, who has to make things go. The entire field of Electricity is covered within its pages. It contains no useless theory; everything is to the point. It teaches you just what you should know about electricity. It is the standard work published on the subject. Forty-one chapters, 610 engravings, handsomely bound in red leather with titles and edges in gold. **$3.50**

ELECTRICITY IN FACTORIES AND WORKSHOPS, ITS COST AND CONVENIENCE. By ARTHUR P. HASLAM. A practical book for power producers and power users showing what a convenience the electric motor, in its various forms, has become to the modern manufacturer. It also deals with the conditions which determine the cost of electric driving, and compares this with other methods of producing and utilizing power. 312 pages. Very fully illustrated. **$2.50**

ELECTRICITY SIMPLIFIED. By PROF. T. O'CONOR SLOANE. The object of "Electricity Simplified" is to make the subject as plain as possible and to show what the modern conception of electricity is; to show how two plates of different metals immersed in acid can send a message around the globe; to explain how a bundle of copper wire rotated by a steam engine can be the agent in lighting our streets, to tell what the volt, ohm and ampere are, and what high and low tension mean; and to answer the questions that perpetually arise in the mind in this age of electricity. 172 pages. Illustrated. **$1.00**

HOW TO BECOME A SUCCESSFUL ELECTRICIAN. By PROF. T. O'CONOR SLOANE. An interesting book from cover to cover. Telling in simplest language the surest and easiest way to become a successful electrician. The studies to be followed, methods of work, field of operation and the requirements of the successful electrician are pointed out and fully explained. 202 pages. Illustrated. **$1.00**

MANAGEMENT OF DYNAMOS. By LUMMIS-PATERSON. A handbook of theory and practice. This work is arranged in three parts. The first part covers the elementary theory of the dynamo. The second part, the construction and action of the different classes of dynamos in common use are described; while the third part relates to such matters as affect the practical management and working of dynamos and motors. 292 pages, 117 illustrations. **$1.50**

STANDARD ELECTRICAL DICTIONARY. By Prof. T. O'CONOR SLOANE. A practical handbook of reference containing definitions of about 5,000 distinct words, terms and phrases. The definitions are terse and concise and include every term used in electrical science. 682 pages, 393 illustrations. **$3.00**

SWITCHBOARDS. By WILLIAM BAXTER, JR. This book appeals to every engineer and electrician who wants to know the practical side of things. All sorts and conditions of dynamos, connections and circuits are shown by diagram and illustrate just how the switchboard should be connected. Includes direct and alternating current boards, also those for arc lighting, incandescent, and power circuits. Special treatment on high voltage boards for power transmission. 190 pages. Illustrated. **$1.50**

TELEPHONE CONSTRUCTION, INSTALLATION, WIRING, OPERATION AND MAINTENANCE. By W. H. RADCLIFFE and H. C. CUSHING. This book gives the principles of construction and operation of both the Bell and Independent instruments; approved methods of installing and wiring them; the means of protecting them from lightning and abnormal currents; their connection together for operation as series or bridging stations; and rules for their inspection and maintenance. Line wiring and the wiring and operation of special telephone systems are also treated. 180 pages, 125 illustrations. **$1.00**

WIRING A HOUSE. By HERBERT PRATT. Shows a house already built; tells just how to start about wiring it. Where to begin; what wire to use; how to run it according to insurance rules, in fact just the information you need. Directions apply equally to a shop. Fourth edition. **25 cents**

WIRELESS TELEPHONES AND HOW THEY WORK. By JAMES ERSKINE-MURRAY. This work is free from elaborate details and aims at giving a clear survey of the way in which Wireless Telephones work. It is intended for amateur workers and for those whose knowledge of Electricity is slight. Chapters contained: How We Hear—Historical—The Conversion of Sound into Electric Waves—Wireless Transmission—The Production of Alternating Currents of High Frequency—How the Electric Waves are Radiated and Received—The Receiving Instruments—Detectors—Achievements and Expectations—Glossary of Technical Work. Cloth. **$1.00**

ENAMELING

HENLEY'S TWENTIETH CENTURY RECEIPT BOOK. Edited by GARDNER D. HISCOX. A work of 10,000 practical receipts, including enameling receipts for hollow ware, for metals, for signs, for china and porcelain, for wood, etc. Thorough and practical. **See page 24 for full description of this book.** **$3.00**

FACTORY MANAGEMENT, ETC.

MODERN MACHINE SHOP CONSTRUCTION, EQUIPMENT AND MANAGEMENT. By O. E. PERRIGO, M.E. A work designed for the practical and every-day use of the Architect who designs, the Manufacturers who build, the Engineers who plan and equip, the Superintendents who organize and direct, and for the information of every stockholder, director, officer, accountant, clerk, superintendent, foreman, and workman of the modern machine shop and manufacturing plant of Industrial America. **$5.00**

FUEL

COMBUSTION OF COAL AND THE PREVENTION OF SMOKE. By WM. M. BARR. To be a success a fireman must be "Light on Coal." He must keep his fire in good condition, and prevent, as far as possible, the smoke nuisance. To do this, he should know how coal burns, how smoke is formed and the proper burning of fuel to obtain the best results. He can learn this, and more too, from Barr's "Combustion of Coal." It is an absolute authority on all questions relating to the Firing of a Locomotive. Nearly 350 pages, fully illustrated. **$1.00**

SMOKE PREVENTION AND FUEL ECONOMY. By BOOTH and KERSHAW. As the title indicates, this book of 197 pages and 75 illustrations deals with the problem of complete combustion, which it treats from the chemical and mechanical standpoints, besides pointing out the economical and humanitarian aspects of the question. **$2.50**

GAS ENGINES AND GAS

CHEMISTRY OF GAS MANUFACTURE. By H. M. ROYLES. A practical treatise for the use of gas engineers, gas managers and students. Including among its contents—Preparations of Standard Solutions, Coal, Furnaces, Testing and Regulation. Products of Carbonization. Analysis of Crude Coal Gas. Analysis of Lime. Ammonia. Analysis of Oxide of Iron. Naphthalene. Analysis of Fire-Bricks and Fire-Clay. Weldom and Spent Oxide. Photometry and Gas Testing. Carburetted Water Gas. Metropolis Gas. Miscellaneous Extracts. Useful Tables. **$4.50**

GAS ENGINE CONSTRUCTION, Or How to Build a Half-Horse-power Gas Engine. By PARSELL and WEED. A practical treatise describing the theory and principles of the action of gas engines of various types, and the design and construction of a half-horse-power gas engine, with illustrations of the work in actual progress, together with dimensioned working drawings giving clearly the sizes of the various details. 300 pages. **$2.50**

GAS, GASOLINE, AND OIL ENGINES. By GARDNER D. HISCOX. Just issued, 18th revised and enlarged edition. Every user of a gas engine needs this book. Simple, instructive, and right up-to-date. The only complete work on the subject. Tells all about the running and management of gas, gasoline and oil engines as designed and manufactured in the United States. Explosive motors for stationary, marine and vehicle power are fully treated, together with illustrations of their parts and tabulated sizes, also their care and running are included. Electric Ignition by Induction Coil and Jump Sparks are fully explained and illustrated, including valuable information on the testing for economy and power and the erection of power plants.

The special information on PRODUCER and SUCTION GASES included cannot fail to prove of value to all interested in the generation of producer gas and its utilization in gas engines.

The rules and regulations of the Board of Fire Underwriters in regard to the installation and management of Gasoline Motors is given in full, suggesting the safe installation of explosive motor power. A list of United States Patents issued on Gas, Gasoline and Oil Engines and their adjuncts from 1875 to date is included. 484 pages. 410 engravings. **$2.50 net**

MODERN GAS ENGINES AND PRODUCER GAS PLANTS. By R. E. Mathot, M.E. A practical treatise of 320 pages, fully illustrated by 175 detailed illustrations, setting forth the principles of gas engines and producer design, the selection and installation of an engine, conditions of perfect operation, producer-gas engines and their possibilities, the care of gas engines and producer-gas plants, with a chapter on volatile hydrocarbon and oil engines. This book has been endorsed by Dugal Clerk as a most useful work for all interested in Gas Engine installation and Producer Gas. **$2.50**

GEARING AND CAMS

BEVEL GEAR TABLES. By D. Ag. Engstrom. No one who has to do with bevel gears in any way should be without this book. The designer and draftsman will find it a great convenience, while to the machinist who turns up the blanks or cuts the teeth, it is invaluable, as all needed dimensions are given and no fancy figuring need be done. **$1.00**

CHANGE GEAR DEVICES. By Oscar E. Perrigo. A book for every designer, draftsman and mechanic who is interested in feed changes for any kind of machines. This shows what has been done and how. Gives plans, patents and all information that you need. Saves hunting through patent records and reinventing old ideas. A standard work of reference. **$1.00**

DRAFTING OF CAMS. By Louis Rouillion. The laying out of cams is a serious problem unless you know how to go at it right. This puts you on the right road for practically any kind of cam you are likely to run up against. **25 cents**

HYDRAULICS

HYDRAULIC ENGINEERING. By Gardner D. Hiscox. A treatise on the properties, power, and resources of water for all purposes. Including the measurement of streams; the flow of water in pipes or conduits; the horse-power of falling water; turbine and impact water-wheels; wave-motors, centrifugal, reciprocating, and air-lift pumps. With 300 figures and diagrams and 36 practical tables. 320 pages. **$4.00**

ICE AND REFRIGERATION

POCKET BOOK OF REFRIGERATION AND ICE MAKING, By A. J. Wallis-Taylor. This is one of the latest and most comprehensive reference books published on the subject of refrigeration and cold storage. It explains the properties and refrigerating effect of the different fluids in use, the management of refrigerating machinery and the construction and insulation of cold rooms with their required pipe surface for different degrees of cold; freezing mixtures and non-freezing brines, temperatures of cold rooms for all kinds of provisions, cold storage charges for all classes of goods, ice making and storage of ice, data and memoranda for constant reference by refrigerating engineers, with nearly one hundred tables containing valuable references to every fact and condition required in the installment and operation of a refrigerating plant. **$1.50**

INVENTIONS—PATENTS

INVENTOR'S MANUAL, HOW TO MAKE A PATENT PAY. This is a book designed as a guide to inventors in perfecting their inventions, taking out their patents, and disposing of them. It is not in any sense a Patent Solicitor's Circular, nor a Patent Broker's Advertisement. No advertisements of any description appear in the work. It is a book containing a quarter of a century's experience of a successful inventor, together with notes based upon the experience of many other inventors. **$1.00**

LATHE PRACTICE

MODERN AMERICAN LATHE PRACTICE. By OSCAR E. PERRIGO. An up-to-date book on American Lathe Work, describing and illustrating the very latest practice in lathe and boring-mill operations, as well as the construction of and latest developments in the manufacture of these important classes of machine tools. 300 pages, fully illustrated. **$2.50**

PRACTICAL METAL TURNING. By JOSEPH G. HORNER. A work of 404 pages, fully illustrated, covering in a comprehensive manner the modern practice of machining metal parts in the lathe, including the regular engine lathe, its essential design, its uses, its tools, its attachments, and the manner of holding the work and performing the operations. The modernized engine lathe, its methods, tools, and great range of accurate work. The Turret Lathe, its tools, accessories and methods of performing its functions. Chapters on special work, grinding, tool holders, speeds, feeds, modern tool steels, etc., etc. **$3.50**

TURNING AND BORING TAPERS. By FRED H. COLVIN. There are two ways to turn tapers; the right way and one other. This treatise has to do with the right way; it tells you how to start the work properly, how to set the lathe, what tools to use and how to use them, and forty and one other little things that you should know. Fourth edition. **25 cents**

LIQUID AIR

LIQUID AIR AND THE LIQUEFACTION OF GASES. By T. O'CONOR SLOANE. Theory, history, biography, practical applications, manufacture. 365 pages. Illustrated. **$2.00**

LOCOMOTIVE ENGINEERING

AIR-BRAKE CATECHISM. By ROBERT H. BLACKALL. This book is a standard text book. It covers the Westinghouse Air-Brake Equipment, including the No. 5 and the No. 6 E T Locomotive Brake Equipment; the K (Quick-Service) Triple Valve for Freight Service; and the Cross-Compound Pump. The operation of all parts of the apparatus is explained in detail, and a practical way of finding their peculiarities and defects, with a proper remedy, is given. It contains 2,000 questions with their answers, which will enable any railroad man to pass any examination on the subject of Air Brakes. Endorsed and used by air-brake instructors and examiners on nearly every railroad in the United States. 23d Edition. 380 pages, fully illustrated with folding plates and diagrams. **$2.00**

AMERICAN COMPOUND LOCOMOTIVES. By Fred H. Colvin. The most complete book on compounds published. Shows all types, including the balanced compound. Makes everything clear by many illustrations, and shows valve setting, breakdowns and repairs. 142 pages. **$1.00**

APPLICATION OF HIGHLY SUPERHEATED STEAM TO LOCOMOTIVES. By Robert Garbe. A practical book. Contains special chapters on Generation of Highly Superheated Steam; Superheated Steam and the Two-Cylinder Simple Engine; Compounding and Superheating; Designs of Locomotive Superheaters; Constructive Details of Locomotives using Highly Superheated Steam; Experimental and Working Results. Illustrated with folding plates and tables. **$2.50**

COMBUSTION OF COAL AND THE PREVENTION OF SMOKE. By Wm. M. Barr. To be a success a fireman must be "Light on Coal." He must keep his fire in good condition, and prevent as far as possible, the smoke nuisance. To do this, he should know how coal burns, how smoke is formed and the proper burning of fuel to obtain the best results. He can learn this, and more too, from Barr's "Combination of Coal." It is an absolute authority on all questions relating to the Firing of a Locomotive. Nearly 350 pages, fully illustrated. **$1.00**

LINK MOTIONS, VALVES AND VALVE SETTING. By Fred H. Colvin, Associate Editor of "American Machinist." A handy book that clears up the mysteries of valve setting. Shows the different valve gears in use, how they work, and why. Piston and slide valves of different types are illustrated and explained. A book that every railroad man in the motive-power department ought to have. Fully illustrated. **50 cents.**

LOCOMOTIVE BOILER CONSTRUCTION. By Frank A. Kleinhans. The only book showing how locomotive boilers are built in modern shops. Shows all types of boilers used; gives details of construction; practical facts, such as life of riveting punches and dies, work done per day, allowance for bending and flanging sheets and other data that means dollars to any railroad man. 421 pages, 334 illustrations. Six folding plates. **$3.00**

LOCOMOTIVE BREAKDOWNS AND THEIR REMEDIES. By Geo. L. Fowler. Revised by Wm. W. Wood, Air-Brake Instructor. Just issued 1910 Revised pocket edition. It is out of the question to try and tell you about every subject that is covered in this pocket edition of Locomotive Breakdowns. Just imagine all the common troubles that an engineer may expect to happen some time, and then add all of the unexpected ones, troubles that could occur, but that you had never thought about, and you will find that they are all treated with the very best methods of repair. Walschaert Locomotive Valve Gear Troubles, Electric Headlight Troubles, as well as Questions and Answers on the Air Brake are all included. 294 pages. Fully illustrated. **$1.00**

LOCOMOTIVE CATECHISM. By Robert Grimshaw. 27th revised and enlarged edition. This may well be called an encyclopedia of the locomotive. Contains over 4,000 examination questions with their answers, including among them those asked at the First, Second and Third year's Examinations. 825 pages, 437 illustrations and 3 folding plates. **$2.50**

NEW YORK AIR-BRAKE CATECHISM. By ROBERT H. BLACKALL. This is a complete treatise on the New York Air-Brake and Air-Signalling Apparatus, giving a detailed description of all the parts, their operation, troubles, and the methods of locating and remedying the same. 200 pages, fully illustrated. **$1.00**

POCKET-RAILROAD DICTIONARY AND VADE MECUM. By FRED H. COLVIN, Associate Editor "American Machinist." Different from any book you ever saw. Gives clear and concise information on just the points you are interested in. It's really a pocket dictionary, fully illustrated, and so arranged that you can find just what you want in a second without an index. Whether you are interested in Axles or Acetylene; Compounds or Counter Balancing; Rails or Reducing Valves; Tires or Turntables, you'll find them in this little book. It's very complete. Flexible cloth cover, 200 pages. **$1.00**

TRAIN RULES AND DESPATCHING. By H. A. DALBY. Contains the standard code for both single and double track and explains how trains are handled under all conditions. Gives all signals in colors, is illustrated wherever necessary, and the most complete book in print on this important subject. Bound in fine seal flexible leather. 221 pages. **$1.50**

WALSCHAERT LOCOMOTIVE VALVE GEAR. By WM. W. WOOD. If you would thoroughly understand the Walschaert Valve Gear, you should possess a copy of this book. The author divides the subject into four divisions, as follows: I. Analysis of the gear. II. Designing and erecting of the gear III. Advantages of the gear. IV. Questions and answers relating to the Walschaert Valve Gear. This book is specially valuable to those preparing for promotion. Nearly 200 pages. **$1.50**

WESTINGHOUSE E T AIR-BRAKE INSTRUCTION POCKET BOOK CATECHISM. By WM. W. WOOD, Air-Brake Instructor. A practical work containing examination questions and answers on the E T Equipment. Covering what the E T Brake is. How it should be operated. What to do when defective. Not a question can be asked of the engineman up for promotion on either the No. 5 or the No. 6 E T equipment that is not asked and answered in the book. If you want to thoroughly understand the E T equipment get a copy of this book. It covers every detail. Makes Air-Brake troubles and examinations easy. Fully illustrated with colored plates, showing various pressures. **$2.00**

MACHINE SHOP PRACTICE

AMERICAN TOOL MAKING AND INTERCHANGEABLE MANUFACTURING. By J. V. WOODWORTH. A practical treatise on the designing, constructing, use, and installation of tools, jigs, fixtures, devices, special appliances, sheet-metal working processes, automatic mechanisms, and labor-saving contrivances; together with their use in the lathe milling machine, turret lathe, screw machine, boring mill, power press, drill, subpress, drop hammer, etc., for the working of metals, the production of interchangeable machine parts, and the manufacture of repetition articles of metal. 560 pages, 600 illustrations. **$4.00**

HENLEY'S ENCYCLOPEDIA OF PRACTICAL ENGINEERING AND ALLIED TRADES. Edited by JOSEPH G. HORNER. A.M.I.Mech.I. This work covers the entire practice of Civil and Mechanical Engineering. The best known experts in all branches of engineering have contributed to these volumes. The Cyclopedia is admirably well adapted to the needs of the beginner and the self-taught practical man, as well as the mechanical engineer, designer, draftsman, shop superintendent, foreman and machinist.

It is a modern treatise in five volumes. Handsomely bound in Half Morocco, each volume containing nearly 500 pages, with thousands of illustrations, including diagrammatic and sectional drawings with full explanatory details. **$25.00** for the complete set of five volumes. **$6.00** per volume, when ordered singly.

MACHINE SHOP ARITHMETIC. By COLVIN-CHENEY. Most popular book for shop men. Shows how all shop problems are worked out and "why." Includes change gears for cutting any threads; drills, taps, shink and force fits; metric system of measurements and threads. Used by all classes of mechanics and for instruction of Y. M. C. A. and other schools. Fifth edition. 131 pages. **50 cents**

MECHANICAL MOVEMENTS, POWERS, AND DEVICES. By GARDNER D. HISCOX. This is a collection of 1890 engravings of different mechanical motions and appliances, accompanied by appropriate text, making it a book of great value to the inventor, the draftsman, and to all readers with mechanical tastes. The book is divided into eighteen sections or chapters in which the subject matter is classified under the following heads: Mechanical Powers, Transmission of Power, Measurement of Power, Steam Power, Air Power Appliances, Electric Power and Construction, Navigation and Roads, Gearing, Motion and Devices, Controlling Motion, Horological, Mining, Mill and Factory Appliances, Construction and Devices, Drafting Devices, Miscellaneous Devices, etc. 11th edition. 400 octavo pages. **$2.50**

MECHANICAL APPLIANCES, MECHANICAL MOVEMENTS AND NOVELTIES OF CONSTRUCTION. By GARDNER D. HISCOX. This is a supplementary volume to the one upon mechanical movements. Unlike the first volume, which is more elementary in character, this volume contains illustrations and descriptions of many combinations of motions and of mechanical devices and appliances found in different lines of Machinery. Each device being shown by a line drawing with a description showing its working parts and the method of operation. From the multitude of devices described, and illustrated, might be mentioned, in passing, such items as conveyors and elevators, Prony brakes, thermometers, various types of boilers, solar engines, oil-fuel burners, condensers, evaporators, Corliss and other valve gears, governors, gas engines, water motors of various descriptions, air ships, motors and dynamos, automobile and motor bicycles, railway block signals, car couples, link and gear motions, ball bearings, breech block mechanism for heavy guns, and a large accumulation of others of equal importance. 1,000 specially made engravings. 396 octavo pages. **$2.50**

SPECIAL OFFER These two volumes sell for $2.50 each, but when the two volumes are ordered at one time from us, we send them prepaid to any address in the world, on receipt of $4.00. You save $1 by ordering the two volumes of Mechanical Movements at one time.

MODERN MACHINE SHOP CONSTRUCTION, EQUIPMENT AND MANAGEMENT. By Oscar E. Perrigo. The only work published that describes the Modern Machine Shop or Manufacturing Plant from the time the grass is growing on the site intended for it until the finished product is shipped. Just the book needed by those contemplating the erection of modern shop buildings, the rebuilding and reorganization of old ones, or the introduction of Modern Shop Methods, Time and Cost Systems. It is a book written and illustrated by a practical shop man for practical shop men who are too busy to read theories and want facts. It is the most complete all-around book of its kind ever published. 400 large quarto pages, 225 original and specially-made illustrations. **$5.00**

MODERN MACHINE SHOP TOOLS; THEIR CONSTRUCTION, OPERATION, AND MANIPULATION. By W. H. Vandervoort. A work of 555 pages and 673 illustrations, describing in every detail the construction, operation, and manipulation of both Hand and Machine Tools. Includes chapters on filing, fitting, and scraping surfaces; on drills, reamers, taps, and dies; the lathe and its tools; planers, shapers, and their tools; milling machines and cutters; gear cutters and gear cutting; drilling machines and drill work; grinding machines and their work; hardening and tempering; gearing, belting and transmission machinery; useful data and tables. **$4.00**

THE MODERN MACHINIST. By John T. Usher. This book might be called a compendium of shop methods, showing a variety of special tools and appliances which will give new ideas to many mechanics from the superintendent down to the man at the bench. It will be found a valuable addition to any machinist's library and should be consulted whenever a new or difficult job is to be done, whether it is boring, milling, turning, or planing, as they are all treated in a practical manner. Fifth edition. 320 pages, 250 illustrations. **$2.50**

MODERN MECHANISM. Edited by Park Benjamin. A practical treatise on machines, motors and the transmission of power, being a complete work and a supplementary volume to Appleton's Cyclopedia of Applied Mechanics. Deals solely with the principal and most useful advances of the past few years. 959 pages containing over 1,000 illustrations; bound in half morocco. **$4.00**

MODERN MILLING MACHINES: THEIR DESIGN, CONSTRUCTION AND OPERATION. By Joseph G. Horner. This book describes and illustrates the Milling Machine and its work in such a plain, clear, and forceful manner, and illustrates the subject so clearly and completely, that the up-to-date machinist, student, or mechanical engineer can not afford to do without the valuable information which it contains. It describes not only the early machines of this class, but notes their gradual development into the splendid machines of the present day, giving the design and construction of the various types, forms, and special features produced by prominent manufacturers, American and foreign. 304 pages, 300 illustrations. **$4.00**

"SHOP KINKS." By Robert Grimshaw. This shows special methods of doing work of various kinds, and reducing cost of production. Has hints and kinks from some of the largest shops in this country and Europe. You are almost sure to find some that apply to your work, and in such a way as to save time and trouble. 400 pages. Fourth edition. **$2.50**

TOOLS FOR MACHINISTS AND WOOD WORKERS, INCLUDING INSTRUMENTS OF MEASUREMENT. By Joseph G. Horner. A practical treatise of 340 pages, fully illustrated and comprising a general description and classification of cutting tools and tool angles, allied cutting tools for machinists and woodworkers; shearing tools; scraping tools; saws; milling cutters; drilling and boring tools; taps and dies; punches and hammers; and the hardening, tempering and grinding of these tools. Tools for measuring and testing work, including standards of measurement; surface plates; levels; surface gauges; dividers; calipers; verniers; micrometers; snap, cylindrical and limit gauges; screw thread, wire and reference gauges, indicators, templets, etc. **$3.50**

MANUAL TRAINING

ECONOMICS OF MANUAL TRAINING. By Louis Rouillion. The only book that gives just the information needed by all interested in manual training, regarding buildings, equipment and supplies. Shows exactly what is needed for all grades of the work from the Kindergarten to the High and Normal School. Gives itemized lists of everything needed and tells just what it ought to cost. Also shows where to buy supplies. **$1.50**

MARINE ENGINEERING

MARINE ENGINES AND BOILERS, THEIR DESIGN AND CONSTRUCTION. By Dr. G. Bauer, Leslie S. Robertson, and S. Bryan Donkin. This work is clearly written, thoroughly systematic, theoretically sound; while the character of its plans, drawings, tables, and statistics is without reproach. The illustrations are careful reproductions from actual working drawings, with some well-executed photographic views of completed engines and boilers. **$9.00 net**

MINING

ORE DEPOSITS OF SOUTH AFRICA WITH A CHAPTER ON HINTS TO PROSPECTORS. By J. P. Johnson. This book gives a condensed account of the ore-deposits at present known in South Africa. It is also intended as a guide to the prospector. Only an elementary knowledge of geology and some mining experience are necessary in order to understand this work. With these qualifications, it will materially assist one in his search for metalliferous mineral occurrences and, so far as simple ores are concerned, should enable one to form some idea of the possibilities of any they may find.

Among the chapters given are: Titaniferous and Chromiferous Iron Oxides—Nickel—Copper—Cobalt—Tin—Molybdenum—Tungsten—Lead—Mercury—Antimony—Iron—Hints to Prospectors. Illustrated. **$2.00**

PRACTICAL COAL MINING. By T. H. Cockin. An important work, containing 428 pages and 213 illustrations, complete with practical details, which will intuitively impart to the reader, not only a general knowledge of the principles of coal mining, but also considerable insight into allied subjects. The treatise is positively up to date in every instance, and should be in the hands of every colliery engineer, geologist, mine operator, superintendent, foreman, and all others who are interested in or connected with the industry. **$2.50**

PHYSICS AND CHEMISTRY OF MINING. By T. H. Byrom. A practical work for the use of all preparing for examinations in mining or qualifying for colliery managers' certificates. The aim of the author in this excellent book is to place clearly before the reader useful and authoritative data which will render him valuable assistance in his studies. The only work of its kind published. The information incorporated in it will prove of the greatest practical utility to students, mining engineers, colliery managers, and all others who are specially interested in the present-day treatment of mining problems. 160 pages. Illustrated. **$2.00**

MISCELLANEOUS

BRONZES. Henley's Twentieth Century Receipt Book contains many practical formulas on bronze casting, imitation bronze, bronze polishes, renovation of bronze. **See page 24 for full description of this book.** **$3.00**

EMINENT ENGINEERS. By Dwight Goddard. Everyone who appreciates the effect of such great inventions as the Steam Engine, Steamboat, Locomotive, Sewing Machine, Steel Working, and other fundamental discoveries, is interested in knowing a little about the men who made them and their achievements.

Mr. Goddard has selected thirty-two of the world's engineers who have contributed most largely to the advancement of our civilization by mechanical means, giving only such facts as are of general interest and in a way which appeals to all, whether mechanics or not. 280 pages, 35 illustrations. **$1.50**

LAWS OF BUSINESS, By Theophilus Parsons, LL.D. The Best Book for Business Men ever Published. Treats clearly of Contracts, Sales, Notes, Bills of Exchange, Agency, Agreement, Stoppage in Transitu, Consideration, Limitations, Leases, Partnership, Executors, Interest, Hotel Keepers, Fire and Life Insurance, Collections, Bonds, Frauds, Receipts, Patents, Deeds, Mortgages, Liens, Assignments, Minors, Married Women, Arbitration, Guardians, Wills, etc. Three Hundred Approved Forms are given. Every Business Man should have a copy of this book for ready reference. The book is bound in full sheep, and Contains 864 Octavo Pages. Our special price. **$3.50**

PATTERN MAKING

PRACTICAL PATTERN MAKING. By F. W. Barrows. This is a very complete and entirely practical treatise on the subject of pattern making, illustrating pattern work in wood and metal. From its pages you are taught just what you should know about pattern making. It contains a detailed description of the materials used by pattern makers, also the tools, both those for hand use, and the more interesting machine tools; having complete chapters on The Band Saw, The Buzz Saw, and The Lathe. Individual patterns of many different kinds are fully illustrated and described, and the mounting of metal patterns on plates for molding machines is included. **$2.00**

PERFUMERY

HENLEY'S TWENTIETH CENTURY BOOK OF RECEIPTS, FORMULAS AND PROCESSES. Edited by G. D. Hiscox. The most valuable Techno-Chemical Receipt Book published. Contains over 10,000 practical Receipts many of which will prove of special value to the perfumer, a mine of information, up to date in every respect. Cloth, **$3.00;** half morocco. **See page 24 for full description of this book.** **$4.00**

PERFUMES AND THEIR PREPARATION. By G. W. ASKINSON, Perfumer. A comprehensive treatise, in which there has been nothing omitted that could be of value to the Perfumer. Complete directions for making handkerchief perfumes, smelling-salts, sachets, fumigating pastilles; preparations for the care of the skin, the mouth, the hair, cosmetics, hair dyes and other toilet articles are given, also a detailed description of aromatic substances; their nature, tests of purity, and wholesale manufacture. A book of general, as well as professional interest, meeting the wants not only of the druggist and perfume manufacturer, but also of the general public. Third edition. 312 pages. Illustrated. **$3.00**

PLUMBING

MODERN PLUMBING ILLUSTRATED. By R. M. STARBUCK. The author of this book, Mr. R. M. Starbuck, is one of the leading authorities on plumbing in the United States. The book represents the highest standard of plumbing work. It has been adopted and used as a reference book by the United States Government, in its sanitary work in Cuba, Porto Rico and the Philippines, and by the principal Boards of Health of the United States and Canada.

It gives Connections, Sizes and Working Data for All Fixtures and Groups of Fixtures. It is helpful to the Master Plumber in Demonstrating to his customers and in figuring work. It gives the Mechanic and Student quick and easy Access to the best Modern Plumbing Practice. Suggestions for Estimating Plumbing Construction are contained in its pages. This book represents, in a word, the latest and best up-to-date practice, and should be in the hands of every architect, sanitary engineer and plumber who wishes to keep himself up to the minute on this important feature of construction. 400 octavo pages, fully illustrated by 55 full-page engravings. **$4.00**

RUBBER

HENLEY'S TWENTIETH CENTURY BOOK OF RECEIPTS, FORMULAS AND PROCESSES. Edited by GARDNER D. HISCOX. Contains upward of 10,000 practical receipts, including among them formulas on artificial rubber. **See page 24 for full description of this book.** **$3.00**

RUBBER HAND STAMPS AND THE MANIPULATION OF INDIA RUBBER. By T. O'CONOR SLOANE. This book gives full details on all points, treating in a concise and simple manner the elements of nearly everything it is necessary to understand for a commencement in any branch of the India Rubber Manufacture. The making of all kinds of Rubber Hand Stamps, Small Articles of India Rubber, U. S. Government Composition, Dating Hand Stamps, the Manipulation of Sheet Rubber, Toy Balloons, India Rubber Solutions, Cements, Blackings, Renovating Varnish, and Treatment for India Rubber Shoes, etc.; the Hektograph Stamp Inks, and Miscellaneous Notes, with a Short Account of the Discovery, Collection, and Manufacture of India Rubber are set forth in a manner designed to be readily understood, the explanations being plain and simple. Second edition. 144 pages. Illustrated. **$1.00**

SAWS

SAW FILING AND MANAGEMENT OF SAWS. By ROBERT GRIMSHAW. A practical hand book on filing, gumming, swaging, hammering, and the brazing of band saws, the speed, work, and power to run circular saws, etc. A handy book for those who have charge of saws, or for those mechanics who do their own filing, as it deals with the proper shape and pitches of saw teeth of all kinds and gives many useful hints and rules for gumming, setting, and filing, and is a practical aid to those who use saws for any purpose. New edition, revised and enlarged. Illustrated. **$1.00**

SCREW CUTTING

THREADS AND THREAD CUTTING. By COLVIN and STABEL. This clears up many of the mysteries of thread-cutting, such as double and triple threads, internal threads, catching threads, use of hobs, etc. Contains a lot of useful hints and several tables. **25 cents**

SHEET METAL WORK

DIES, THEIR CONSTRUCTION AND USE FOR THE MODERN WORKING OF SHEET METALS. By J. V. WOODWORTH. A new book by a practical man, for those who wish to know the latest practice in the working of sheet metals. It shows how dies are designed, made and used, and those who are engaged in this line of work can secure many valuable suggestions. **$3.00**

PUNCHES, DIES AND TOOLS FOR MANUFACTURING IN PRESSES. By J. V. WOODWORTH. A work of 500 pages and illustrated by nearly 700 engravings, being an encyclopedia of die-making, punch-making, die sinking, sheet-metal working, and making of special tools, subpresses, devices and mechanical combinations for punching, cutting, bending, forming, piercing, drawing, compressing, and assembling sheet-metal parts and also articles of other materials in machine tools. **$4.00**

STEAM ENGINEERING

AMERICAN STATIONARY ENGINEERING. By W. E. CRANE. A new book by a well-known author. Begins at the boiler room and takes in the whole power plant. Contains the result of years of practical experience in all sorts of engine rooms and gives exact information that cannot be found elsewhere. It's plain enough for practical men and yet of value to those high in the profession. Has a complete examination for a license. **$2.00**

BOILER ROOM CHART. By GEO. L. FOWLER. A Chart —size 14 x 28 inches—showing in isometric perspective the mechanisms belonging in a modern boiler room. Water tube boilers, ordinary grates and mechanical stokers, feed water heaters and pumps comprise the equipment. The various parts are shown broken or removed, so that the internal construction is fully illustrated. Each part is given a reference number, and these, with the corresponding name, are given in a glossary printed at the sides. This chart is really a dictionary of the boiler room—the names of more than 200 parts being given. It is educational—worth many times its cost. **25 cents**

ENGINE RUNNER'S CATECHISM. By ROBERT GRIMSHAW. Tells how to erect, adjust, and run the principal steam engines in use in the United States. The work is of a handy size for the pocket. To young engineers this catechism will be of great value, especially to those who may be preparing to go forward to be examined for certificates of competency; and to engineers generally it will be of no little service as they will find in this volume more really practical and useful information than is to be found anywhere else within a like compass. 387 pages. Sixth edition. **$2.00**

ENGINE TESTS AND BOILER EFFICIENCIES. By J. BUCHETTI. This work fully describes and illustrates the method of testing the power of steam engines, turbine and explosive motors. The properties of steam and the evaporative power of fuels. Combustion of fuel and chimney draft; with formulas explained or practically computed. 255 pages, 179 illustrations. **$3.00**

HORSE POWER CHART. Shows the horse power of any stationary engine without calculation. No matter what the cylinder diameter or stroke; the steam pressure or cut-off; the revolutions, or whether condensing or non-condensing, it's all there. Easy to use, accurate, and saves time and calculations. Especially useful to engineers and designers. **50 cents**

MODERN STEAM ENGINEERING IN THEORY AND PRACTICE. By GARDNER D. HISCOX. This is a complete and practical work issued for Stationary Engineers and Firemen dealing with the care and management of Boilers, Engines, Pumps, Superheated Steam, Refrigerating Machinery, Dynamos, Motors, Elevators, Air Compressors, and all other branches with which the modern Engineer must be familiar. Nearly 200 Questions with their Answers on Steam and Electrical Engineering, likely to be asked by the Examining Board, are included. 487 pages, 405 engravings. **$3.00**

STEAM ENGINE CATECHISM. By ROBERT GRIMSHAW. This volume of 413 pages is not only a catechism on the question and answer principle; but it contains formulas and worked-out answers for all the Steam problems that appertain to the operation and management of the Steam Engine. Illustrations of various valves and valve gear with their principles of operation are given. 34 tables that are indispensable to every engineer and fireman that wishes to be progressive and is ambitious to become master of his calling are within its pages. It is a most valuable instructor in the service of Steam Engineering. Leading engineers have recommended it as a valuable educator for the beginner as well as a reference book for the engineer. Sixteenth edition. **$2.00**

STEAM ENGINEER'S ARITHMETIC. By COLVIN-CHENEY. A practical pocket book for the Steam Engineer. Shows how to work the problems of the engine room and shows "why." Tells how to figure horse-power of engines and boilers; area of boilers; has tables of areas and circumferences; steam tables; has a dictionary of engineering terms. Puts you onto all of the little kinks in figuring whatever there is to figure around a power plant. Tells you about the heat unit; absolute zero; adiabatic expansion; duty of engines; factor of safety; and 1,001 other things; and everything is plain and simple—not the hardest way to figure, but the easiest. **50 cents**

STEAM HEATING AND VENTILATION

PRACTICAL STEAM, HOT-WATER HEATING AND VENTILATION. By A. G. King. This book is the standard and latest work published on the subject and has been prepared for the use of all engaged in the business of steam, hot-water heating and ventilation. It is an original and exhaustive work. Tells how to get heating contracts, how to install heating and ventilating apparatus, the best business methods to be used, with "Tricks of the Trade" for shop use. Rules and data for estimating radiation and cost and such tables and information as make it an indispensable work for everyone interested in steam, hot-water heating and ventilation. It describes all the principal systems of steam, hot-water, vacuum, vapor and vacuum-vapor heating, together with the new accelerated systems of hot-water circulation, including chapters on up-to-date methods of ventilation and the fan or blower system of heating and ventilation.

You should secure a copy of this book, as each chapter contains a mine of practical information. 367 pages, 300 detailed engravings. **$3.00**

STEAM PIPES

STEAM PIPES: THEIR DESIGN AND CONSTRUCTION. By Wm. H. Booth. The work is well illustrated in regard to pipe joints, expansion offsets, flexible joints, and self-contained sliding joints for taking up the expansion of long pipes. In fact, the chapters on the flow of Steam and expansion of pipes are most valuable to all steam fitters and users. The pressure strength of pipes and method of hanging them is well treated and illustrated. Valves and by-passes are fully illustrated and described, as are also flange joints and their proper proportions. Exhaust heads and separators. One of the most valuable chapters is that on superheated steam and the saving of steam by insulation with the various kinds of felting and other materials, with comparison tables of the loss of heat in thermal units from naked and felted steam pipes. Contains 187 pages. **$2.00**

STEEL

AMERICAN STEEL WORKER. By E. R. Markham. The standard work on hardening, tempering and annealing steel of all kinds. A practical book for the machinist, tool maker or superintendent. Shows just how to secure best results in any case that comes along. How to make and use furnaces and case harden; how to handle high-speed steel and how to temper for all classes of work. **$2.50**

HARDENING, TEMPERING, ANNEALING, AND FORGING OF STEEL. By J. V. Woodworth. A new book containing special directions for the successful hardening and tempering of all steel tools. Milling cutters, taps, thread dies, reamers, both solid and shell, hollow mills, punches and dies, and all kinds of sheet-metal working tools, shear blades, saws, fine cutlery and metal-cutting tools of all descriptions, as well as for all implements of steel both large and small, the simplest, and most satisfactory hardening and tempering processes are presented. The uses to which the leading brands of steel may be adapted are concisely presented, and their treatment for working under different conditions explained, as are also the special methods for the hardening and tempering of special brands. 320 pages, 250 illustrations. **$2.50**